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October 2009

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THE MILKY WAY

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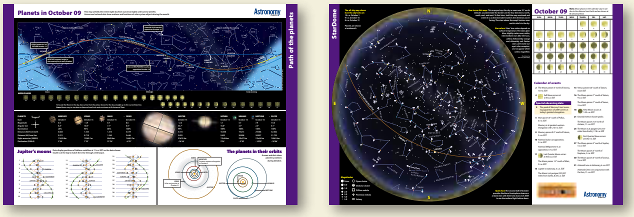

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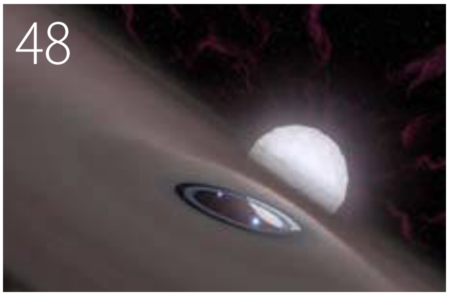

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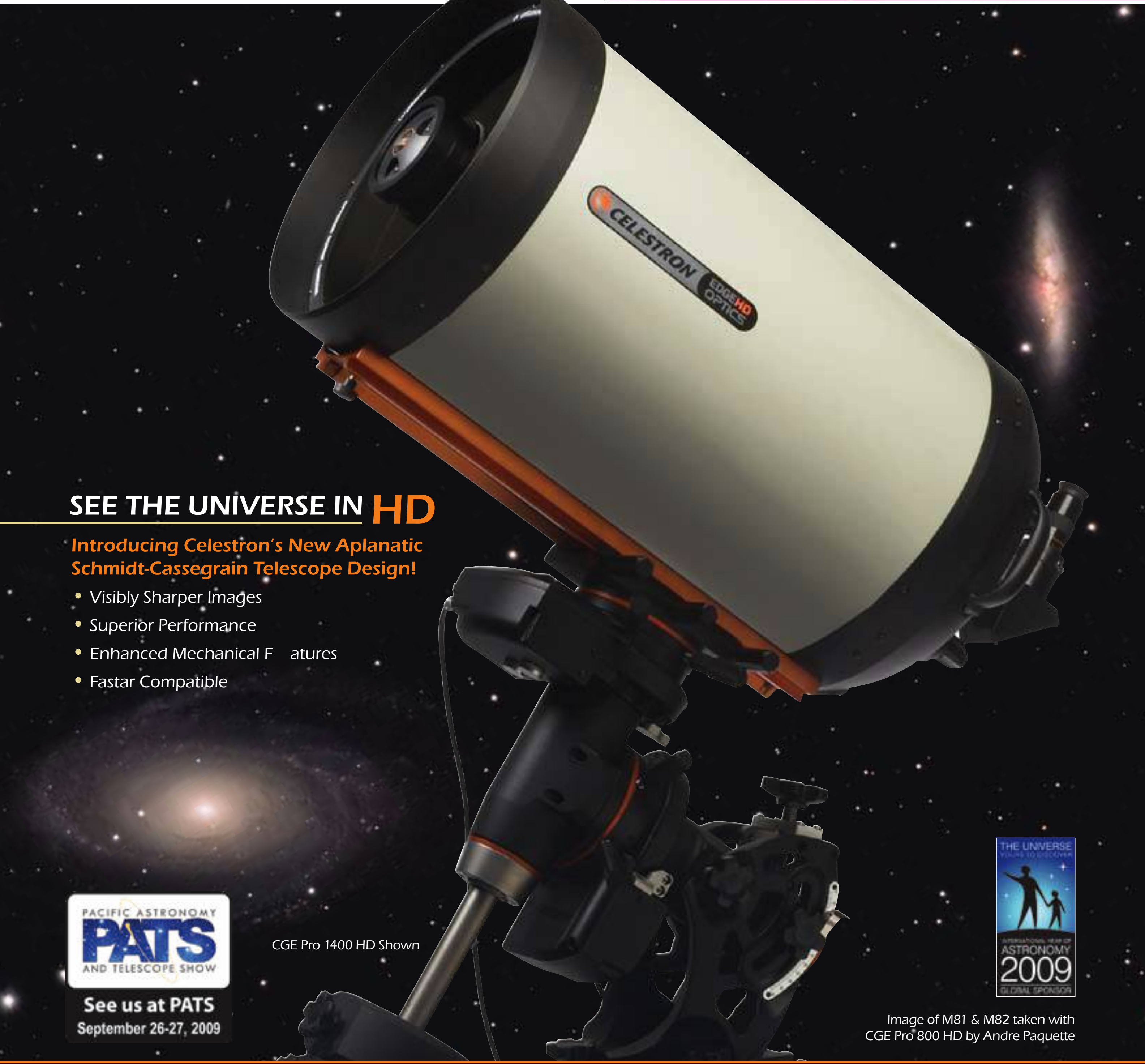

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This Month in *Astronomy*

Why you should register on Astronomy.com

by David J. Eicher

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The growing list of online features that are available exclusively to subscribers, for free, includes our new Equipment Review Archive. This searchable database contains more than 200 reviews of telescopes, binoculars, cameras, and accessories for amateur astronomers, as well as other information from the past several years of the magazine. This tremendous amount of content is available online to those who register.

Our StarDome interactive star chart is available to everyone on the site. However, StarDome Plus, an enhanced version with more objects shown, is available to subscribers — those who register.

Our online, zoomable Star Atlas, with 45,000 stars, thousands of deep-sky objects, and 24 searchable sky maps covering the entire heavens, is available to those who register.

Web extras that correlate to published magazine stories are another big plus. This month, they include a story about Edwin Hubble's discovery of galaxies, how to observe the weird star Epsilon Aurigae, the list of 109 cosmic Ghost Hunt objects, and when to observe the "Lunar X" this year. All this is available to those who register.

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Editor

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What *Really* Is the Universe Made of? Welcome to the Dark Side

Tackle This Intriguing Cosmic Question with a Theoretical Physicist at the California Institute of Technology

There's more to the universe than meets the eye—a lot more. In recent years scientists have discovered that 95 percent of the contents of the cosmos is invisible to all of our current methods of direct detection. Yet something is definitely there, holding galaxies and galaxy clusters together, and governing the shape and fate of the universe.

Scientists call these invisible components dark matter and dark energy—"dark" because these phenomena don't emit light, not because we aren't learning more and more about them. Indeed, dark matter and dark energy are the most eagerly studied subjects in astronomy and particle physics today. And for good reason—what could be more exciting than cracking the mystery of the fundamental constituents and overall composition of the universe?

A Mind-Expanding Experience

You can join the search in this mind-expanding course of 24 lectures taught by a scientist with a profound knowledge of the field. A theoretical physicist at the California Institute of Technology, Dr. Sean Carroll has a knack for explaining the latest complex picture of the universe in easy-to-follow terms—a skill honed through his many public lectures and radio and television appearances.

You will find Dr. Carroll relaxed, eloquent, wryly funny, and brimming with ideas as he takes you on a voyage of scientific discovery: from the early 20th-century work of Albert Einstein in theoretical physics and Edwin Hubble in observational astronomy, who each contributed key insights to the revolutionary view of an expanding universe, to the powerful elaboration of these concepts that has brought us, for the first time in human history, to the brink of knowing what the universe is made of.

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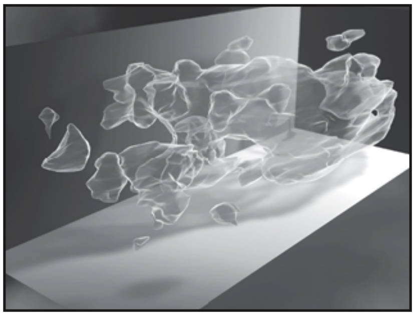

NASA, ESA and R. Massey (California Institute of Technology).

The distribution of dark matter in the universe

About Your Professor

Professor Sean Carroll is a Senior Research Associate in Physics at the California Institute of Technology. He received his Ph.D. in Astrophysics from Harvard, did postdoctoral research at MIT and UC Santa Barbara, and taught at the University of Chicago. He has received research grants from NASA, the U.S. Department of Energy, and the National Science Foundation. In 2006 he was awarded the Arts and Sciences Alumni Medallion from Villanova University.

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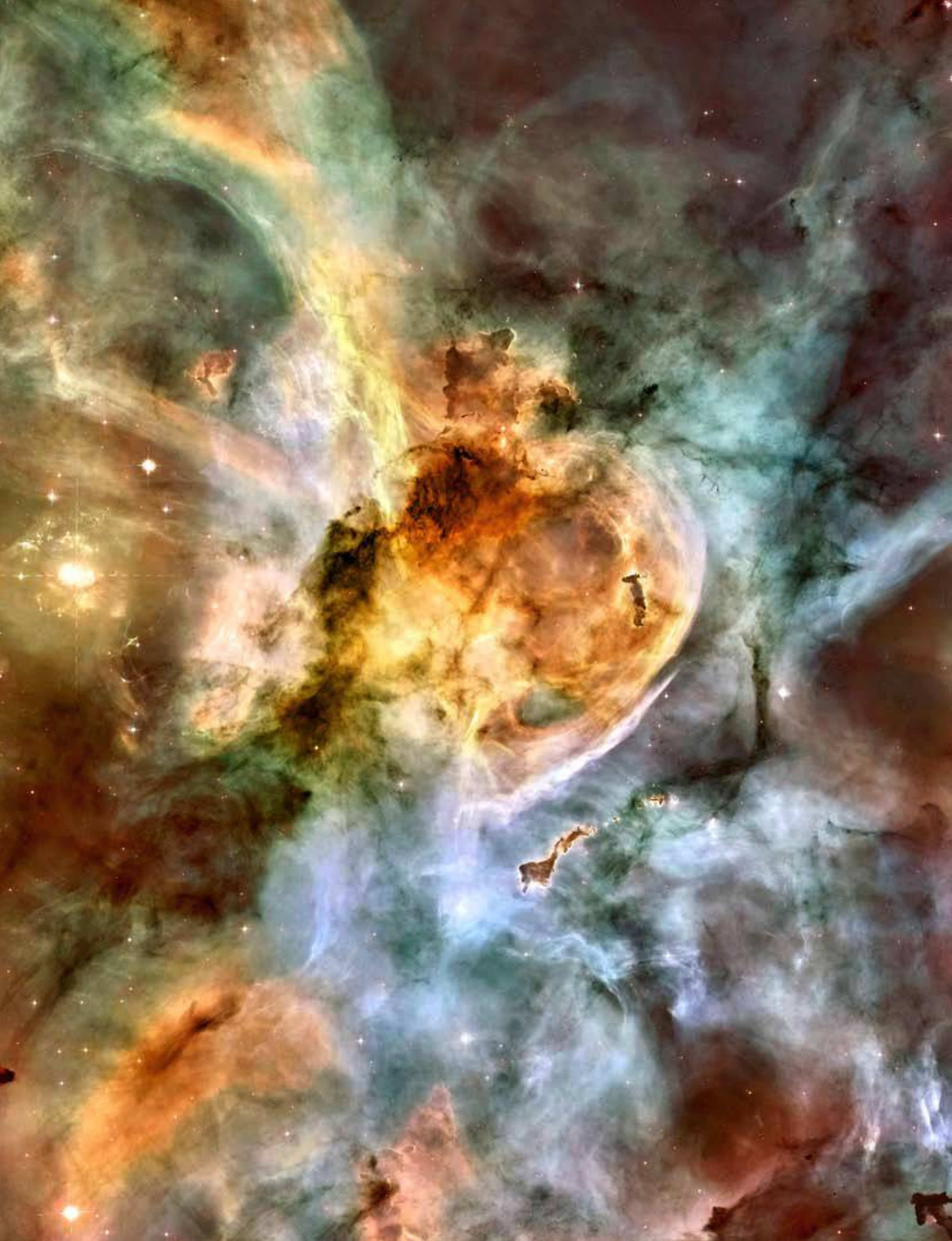
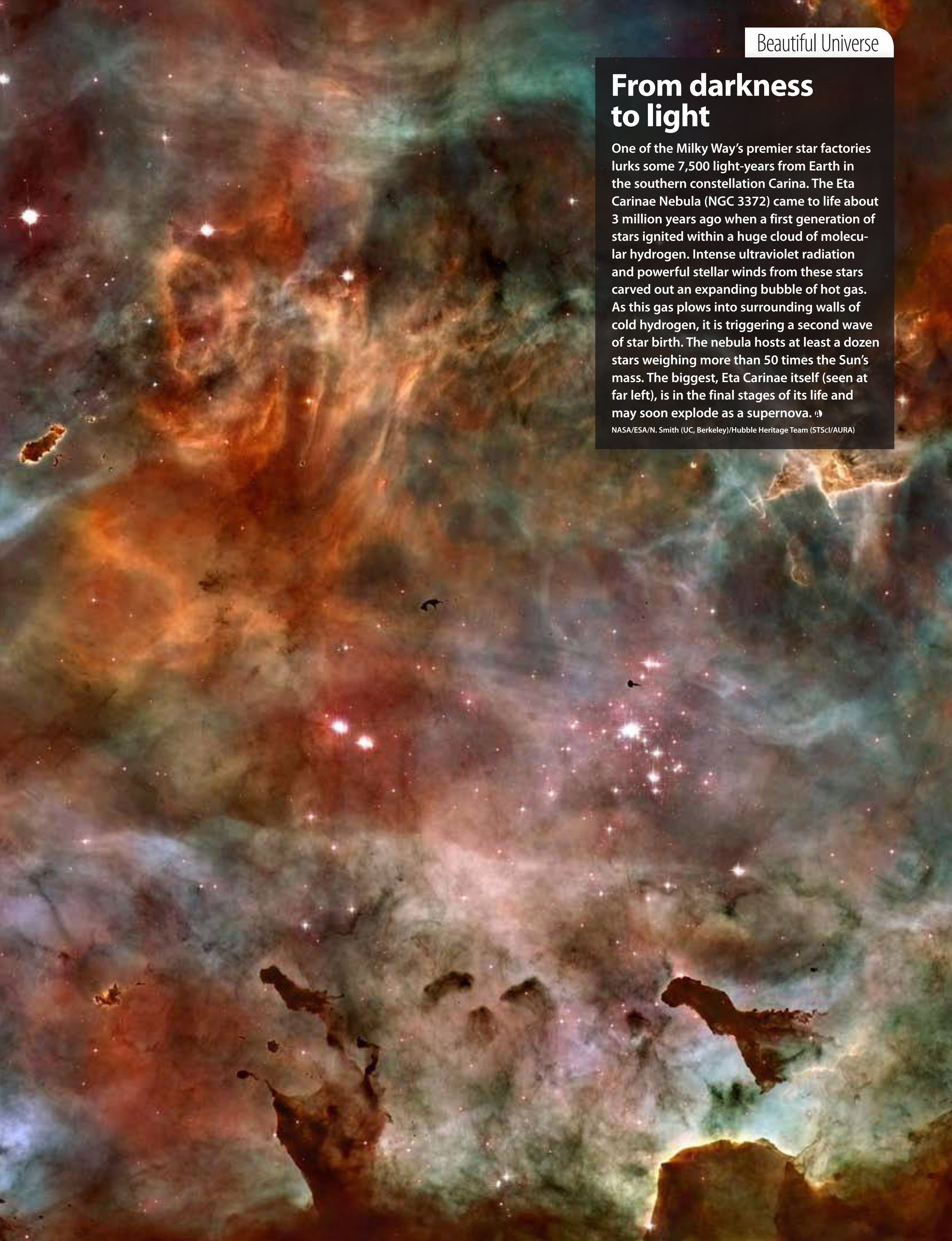




From darkness to light

One of the Milky Way's premier star factories lurks some 7,500 light-years from Earth in the southern constellation Carina. The Eta Carinae Nebula (NGC 3372) came to life about 3 million years ago when a first generation of stars ignited within a huge cloud of molecular hydrogen. Intense ultraviolet radiation and powerful stellar winds from these stars carved out an expanding bubble of hot gas. As this gas plows into surrounding walls of cold hydrogen, it is triggering a second wave of star birth. The nebula hosts at least a dozen stars weighing more than 50 times the Sun's mass. The biggest, Eta Carinae itself (seen at far left), is in the final stages of its life and may soon explode as a supernova.

NASA/ESA/N. Smith (UC, Berkeley)/Hubble Heritage Team (STScI/AURA)

Astroconfidential

Go beyond the latest discovery, research, or theory and meet the professionals who make it all possible.

by Karri Ferron

GETTING TO KNOW

Amy **Mainzer**

Wide-field Infrared Survey Explorer (WISE) Deputy Project Scientist at the Jet Propulsion Laboratory in Pasadena, California

Whitney Clavin

Best thing about working on WISE: I like that WISE is a fast-paced project that should produce stunning results in a mind-boggling array of areas, and it will do so on a relatively short time scale for a space mission. An all-sky survey is one of the most fundamental tools in astronomy, so you can be sure that the project will make a great impact across the field. I also enjoy the varied technical challenges of working on the WISE design and testing. As an astronomer with a focus on instrumentation, I always have something new and interesting to think about. One day it's detectors, the next it's data compression, then cryogenics, electronics, optics, etc. This field is never boring!

Greatest accomplishment so far: I'm really proud of the instrument that I built for the Spitzer Space Telescope. It's a small camera called the Pointing Calibration and Reference Sensor that serves as the fine guidance sensor for the observatory. It tells Spitzer where to point with high precision. It's been in use continuously for more than 5 years now, so if you've used Spitzer, you've used my instrument. I'm thrilled to have contributed to all the great science that Spitzer has accomplished. It's been like a constant, steady heartbeat the past 5 years, knowing that it's up there working away no matter what I'm doing down here.

Best way to get more people interested in astronomy: Professional astronomers need to recognize that it's not just in our interest to make sure people are interested in astronomy; it's a necessity. Most of our work is taxpayer supported, and an educated public is a voting public. Plus, astronomy is profoundly socially relevant, and we are obligated to share what we learn. That means treating public outreach as a regular job responsibility, not an optional extra. If we're genuinely enthusiastic about the science and make an effort to communicate that, people pick up on it and become interested, as well. So at a minimum, we must talk to kids, friends, neighbors, etc. It matters.

Astro**influences**

How did you get interested in making maps of celestial objects?

I became interested in making maps of bodies in the solar system while trying to find ways to identify landmarks to use for spacecraft navigation. The concepts involved are simple, but it takes a computer to figure it out.

We see in stereo. Each eye gives us a different view of the same thing. An early use of photography was to take pictures of the same scene from two slightly different positions. These photos were used to make peep shows, forerunners of the current generation of 3-D movies. The same method is used in stereographic analysis, from aerial surveys to mapping from spacecraft. It's not very accurate because separations are relatively small. The two scenes must be almost identical in scale and illumination to identify the common points.

Stereo isn't the only clue our eyes receive. When we look at an object, we see light and dark areas. Some areas are intrinsically light or dark, while others change with differing illumination.

From the way a piece of surface appears at different illuminations, we can build a 3-D "maplet" that describes its topography and intrinsic brightness. We then can tie hundreds of diverse images to one another through a common maplet to precisely position the maplet and its topography on the body. By combining many maplets, we can build accurate topography for a body to study it or to navigate spacecraft around it.

Courtesy Robert Gaskell

Robert **Gaskell**

Senior scientist at the Planetary Science Institute in Tucson, Arizona

Astro**ideas**

Where is the study of dark matter and dark energy going?

EINSTEIN'S TELESCOPE

A new tool that is central to current and future efforts in search of dark matter and dark energy is a technique called gravitational lensing.

Dark matter and dark energy are invisible to even our most powerful telescopes, but any clump of matter (including dark matter) leaves a dimple or warp in space-time. Light traveling through the universe follows the curves of these warps, bending around a massive object as if a giant lens were out in space. The "lens" may be invisible — such as the dark matter in a cluster of galaxies — but we can trace its shape and infer its size from the way it modifies our views of objects behind it.

The goal of gravitational-lensing experiments is to map the dark matter in the universe. Details of how dark matter congregates in galaxies and clusters can help test and refine current cosmological models and provide clues to the nature of dark matter.

Even more tantalizing is the potential to detect the influence of dark energy on the universe. Several future dark-energy experiments will measure the subtle distortions in the images of millions (or billions) of distant galaxies caused by gravitational lensing — and from this extract the imprint of dark energy.

Doug McGoldrick

Evalyn **Gates**

Assistant director of the Kavli Institute for Cosmological Physics at the University of Chicago

To learn more about the people featured this month, visit www.Astronomy.com/toc.

OUR TURN

Caty **Pilachowski**

Kirkwood Chair in Astronomy at Indiana University in Bloomington

Julia Wilson

What are the current big ideas in the study of star clusters?

Star clusters are nature's star laboratories, for two reasons. First, they give us a way to test models of stellar evolution by providing star samples of well-determined ages, distances, and chemical compositions. Clusters also are important indicators of stellar populations in galaxies, including our own.

It's hard to pin down just a few of the "big ideas." A couple of the biggest are what we can learn about the early evolution of planetary systems and also what we can learn about the origin and evolution of galaxies — the first from very young star clusters, and the second from the oldest star clusters, the globular clusters.

How did you get interested in instrumentation?

An observational astronomer has to be interested in instrumentation! We're always struggling to get fainter sources, more resolution and signal-to-noise, and to lock onto our targets faster.

I began working on globular clusters in the 1970s with George Wallerstein, but it was so frustrating trying to untangle what was happening one star at a time. The multi-object spectrographs let us get great spectra of hundreds of stars and begin to see the big picture. It's the instrumentation that lets us make the major advances.

What goals do you have for the next 5 years?

Too many! First, I'd like to complete a spectrograph designed to produce a complete survey of bright stars — and get that survey started. Second, operators of the WIYN telescope (which consists of the University of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatory) are building a new One Degree Imager (ODI) with a 1,000 megapixel camera, and I want to use it to explore the outer reaches of globular clusters in several new ways. And, of course, I need to figure out how to find more hours in a day.

> ***"Clusters are nature's star laboratories."***
> **— Caty Pilachowski**

Daniel B. Phillips

What is the greatest challenge facing astronomy?

In the United States, our greatest challenge for astronomy is learning to work together — to take the fullest advantage of what we can do by combining both federal and private investment in our field.

Foundations and private donors have made possible great discoveries in astronomy, but the big, new projects of the next decade — the Large Synoptic Survey Telescope (LSST) and the 20-, 30-, and 40-meter telescopes we want to build — are of such a large vision that we need to combine forces to make them happen. Can we do it? I hope so!

Astro**fascinations**

What fascinates you most about studying the Cosmic Dark Ages?

Volker **Bromm**

Associate professor in the Department of Astronomy at the University of Texas at Austin

Sasha Haagensen

The Cosmic Dark Ages is a mysterious epoch beyond what is observable with today's best telescopes. It's where we predict the first stars, galaxies, and black holes formed a few hundred million years after the Big Bang.

The veil is about to be lifted on the end of this era with NASA's James Webb Space Telescope (JWST), planned for 2014. The mission will image the first sources of light, so now is the time to push our theoretical and computational tools to predict what the JWST might find. It's a wonderful challenge: Try as hard as you possibly can to unravel the mysteries of the early universe, and in a few years observational astronomers will tell you whether you got it right!

The key problem we faced in the late 1990s was determining the masses of the first stars. We knew all the relevant laws that would govern their formation, but we had to push what was computationally possible to uncover the first stars' masses.

We discovered that the first stars were likely much more massive than stars in the present-day universe, with typical masses of 100 times that of our Sun. From this, a number of predictions followed that the JWST will explore — most importantly, that the first stars would live only a few million years, produce enormous amounts of high-energy radiation, and eventually die in colossal "hypernova" explosions, thus spewing the first heavy chemical elements into the cosmic gas.

We continually improve predictions by exploiting advances in supercomputer technology. And we are preparing for the ultimate test, when the JWST will explore the final frontier of cosmology.

Letters

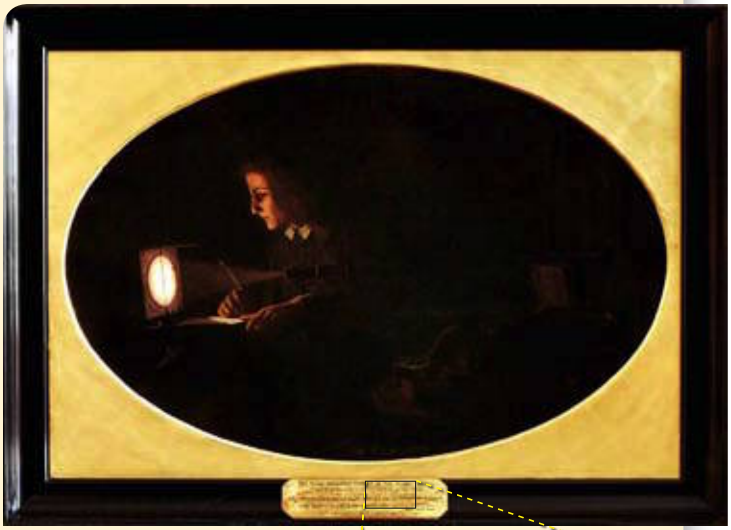
New versus old

In your May issue on page 34, left column, author Ray Shubinski says Jeremiah Horrocks calculated that Venus would transit the Sun late Sunday, November 24, 1639. My calculations and checks of Internet calendar programs show that November 24, 1639, was a Thursday on the Gregorian present-day calendar. Is this day-of-the-week difference due to Horrocks using a different calendar? — **Alfred B. Babcock,** Port Townsend, Washington

You are correct that the different dates have to do with the calendars in effect at the time. Although Catholic countries adopted the Gregorian calendar in 1583, Britain (and the United States) remained on the Julian calendar until 1752. Because Horrocks was in England, the transit occurred on Sunday, November 24 (in the Julian calendar). That's why he was attending to his church and why it made sense to use the Julian date in our article.

The plaque at the bottom of the painting on page 34 says the date he observed the transit was 24th November (O.S.) 1639, where the "O.S." refers to "Old System."

For what it's worth, the Gregorian date for this transit was December 4, 1639. — **Richard Talcott,** Senior Editor



THE PLANET VENUS

Jeremiah Horrocks observed Venus transit the Sun Sunday, November 24, 1639, in the Julian calendar. J. W. Lavender painting, courtesy Astley Hall Museum and Art Gallery

A research challenge

William Sheehan reminds us in May's "Experience Galileo's Italy" of the well-known mistreatment of Galileo in the 17th century. It's easy but fruitless to expostulate with hindsight about the blunders of history. More to the point, how do we move forward? Have Galileo's experiences taught us to avoid similar blunders today? Galileo paid a price for challenging the Renaissance establishment. Is there not also a price for disregarding the doctrines of current establishments?

In the field of geology, Alfred Wegener was excoriated for decades by the leading researchers in the field in the early 1900s for his then-outrageous teaching about continental drift. Similar cases are found in virtually every discipline.

Human nature hasn't changed much since 1631. Vocabularies are now contemporary and terms are different. But egos remain egos, and powerful egos resent challenges to their influence, status, reputation, and vested interests. The scientific establishment has not been immune.

Defying commonly accepted doctrines remains heretical even in the 21st century. — **Robert Beyerle,** Greer, South Carolina

Interpreting sunsets

Thanks for Stephen James O'Meara's May article, "A volcanic sunset." When I started amateur stargazing in fall 2007, I began to take note of strikingly yellow horizons during sunset. I am a meteorologist, so I associated the yellow sunsets (and a notable lack of red) with particularly dry air and consequently opportunities for deep-sky observing. For about a year, those days had been relatively few in number here in Norman, Oklahoma.

In recent months, however, I have seen quite an increase in the number of days with bright-yellow horizons at sunset. I attributed the increase to an exceptional dry spell that we entered in September 2008 and only began coming out of in April 2009. Some of the yellow sunsets puzzled me, however, because I saw a distinct rosy-red color atop the bright yellow, and on some occasions I knew that the lowest atmosphere layer was not as dry as it had been each time I observed bright-yellow sunsets in the past.

I didn't think too hard to solve this mystery, but thankfully O'Meara did! The May column fits what I remember seeing, and I will certainly be on the lookout for these sunsets in the future.

Incidentally, this is the second time *Astronomy* magazine has explained to me something that I hadn't realized I had seen. During a 1-year stay in rural Williston, North Dakota, I had several opportunities to marvel at a glow rising from the western horizon a few hours after sunset. I found this distinct and large wedge of soft white light mesmerizing. A couple years later while reading *Astronomy*, I was ecstatic to find that I had seen the zodiacal light! — **Patrick Burke,** Norman, Oklahoma

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We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Webtalk

Eagle Nebula, by Jim Wood

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MULTIMEDIA

Great deep-sky targets for the fall

Featured video

In "Autumn observing targets for large telescopes," *Astronomy* magazine Editor David J. Eicher highlights objects you can see this fall using a 12-inch or larger telescope.

Podcasts

Senior Editor Michael E. Bakich's weekly series highlights one great target for beginning observers, as well as small- and large-telescope objects.

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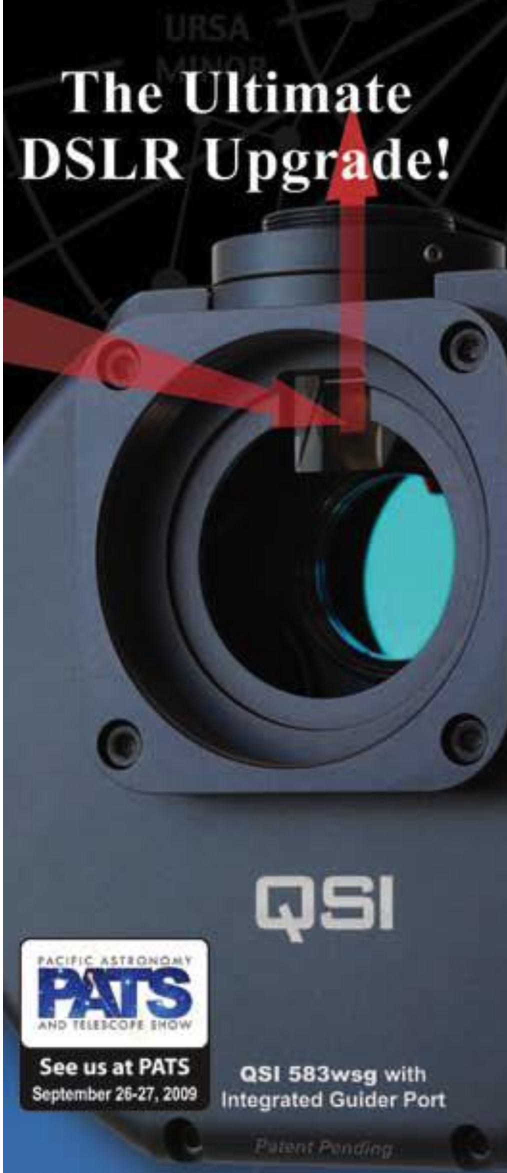
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Strange Universe

by Bob Berman

A dozen cool facts

These morsels of information prove we really live in a strange universe.

Whenever I come across far-out facts or something cool emerges from a calculation, I jot it down. I figure you may like it, too. Such science nuggets usually become part of an article, but right now a bunch are scattered around my desk going nowhere. So, I'll just toss them at you.

1. Neutrons live forever when snuggled inside atoms. They still look fresh and have that "new car smell" after 10 billion years; they outlast stars. But if a neutron escapes its atom, it pays a bizarre price for its freedom. Roaming loose, the average neutron decays and vanishes in 10½ minutes. What's the lesson here? Stay home with your parents?

2. We've found 34 meteorites from Mars that have landed on Earth. Some are for sale. How do we know their origins? The secret involves elements with unusual numbers of neutrons, called isotopes. A tiny fraction of oxygen atoms have 10 neutrons instead of the normal 8, which is noted as ^{18}O. In every kind of earthly material, the proportion of ordinary oxygen to ^{18}O is always similar. But the ratio is different on Mars — the telltale fingerprint that proves a rock is not from Earth.

3. The Moon rings like an enormous gong. When unneeded spacecraft are sent crashing onto the lunar surface, the Moon still shakes 2 hours later. By contrast, impacts on Earth dampen out in just a minute or two. Explanation: The Moon must have a solid core like a giant crystal that transmits vibrations, unlike Earth with its liquidy creamy nougat center.

4. Rainbows don't cast reflections. They can't because they're not real objects. As we all know from horror movies, vampires don't have a reflection in a mirror. Neither do rainbows.

5. There are as many oxygen atoms in a breath of air as there are breaths of air in all of Earth's atmosphere.

6. Helium, a pathological loner that combines stably with nothing, is the universe's only substance that is never solid. Even in the coldest natural environments, it stays a gas or a strange liquid with zero viscosity (no "thickness") that will flow anywhere, even uphill. As for your munchkin voice if you inhale a little helium from a party balloon, that happens because sound travels 760 mph (1,225 km/h) through air, but a weird, screaming 2,175 mph (3,500 km/h) through helium. You're hearing your own voice moving at Mach 3.

7. If you dug a hole to the center of Earth and onward to the opposite surface and then jumped in, how long would it take you to fall to Earth's core? Answer: Ignoring air resistance, 45 minutes. After passing the center, you'd continue on, slower and slower, until you reached the rim of the opposite hole in another 45 minutes. So, 90 minutes to fall through Earth's diameter. Ninety minutes is also the orbital period of the space shuttle and the International Space Station. Bottom line: You would fall around our planet or through it in the same amount of time.

Neutrons still look fresh and have that "new car smell" after 10 billion years.

7a. While we're at it, if you failed to grab the hole's rim on the Australian side so that you fell back through Earth a second time, would you reach all the way to where you started? Or would you instead lose a little distance with each passage, the way a bouncing ball loses height with every bounce? Answer: Ignoring air resistance again, you'd go all the way, back and forth, forever.

8. Want to be the only one on your cellblock to know the Sun's weight? Easy. It's 2 octillion tons. That's 27 zeros. And Earth weighs 6 octillion grams. Over time, the Sun gets lighter. Meanwhile, Earth keeps getting heavier. Eventually, we'll be the same size. But we'll never be the same weight.

9. The Sun weighs 4 million tons less each second. This dramatic weight loss regimen results from nuclear fusion continually converting mass into energy.

10. The Kepler mission is looking for "another Earth." But what about "another Sun"? Of the 1,000 nearest stars within 3 dozen light-years, only one matches our Sun's temperature, size, and luminosity and has the same precise spectral class of G2V (a main sequence star with a surface temperature of about 9980° Fahrenheit [5525° Celsius]). Where is this twin? Oddly enough, it's the nearest naked-eye star. Alpha Centauri A. What are the chances of that?

11. The mirror of the first big telescope of the 20th century, the 100-inch reflector on Mount Wilson in California, was made of wine-bottle glass. That's why it's green.

12. The universe's coldest place is nowhere in space. It's on Earth. Specifically, it's 77 Massachusetts Avenue, Bldg. 26, Cambridge, Massachusetts: German physicist Wolfgang Ketterle's lab at the Massachusetts Institute of Technology holds the world record for coldest temperature — 810 trillionths of a degree Fahrenheit above absolute zero.

Now I can toss those scraps of paper away. Thanks for helping out.

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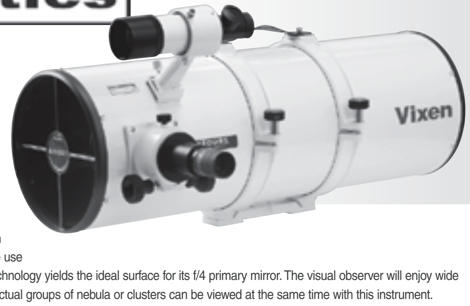

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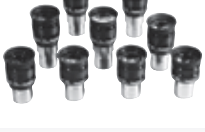

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Evening Stars

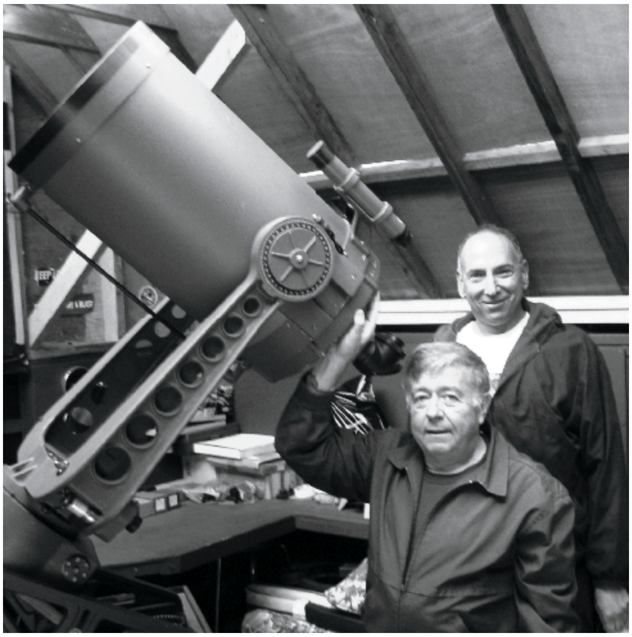
by David H. Levy

Kingston's astronomical dynamo

This amateur's interests lie in astronomy and literature.

Imagine a large hall on a busy university campus in September 1977. The event was called "Clubs Night," and organizers had arranged tables all over the room for groups representing everything from swimming and hiking to activities scientific and cultural.

I was walking from table to table until I found, not far from a corner, a quieter-than-usual section of the big room. There, at a small table, sat Leo Enright. A portly man then in his 40s, Leo taught English and classics at Sharbot Lake High School, about an hour's drive north of Kingston, Ontario. In our first conversation, I mentioned that I was getting my master's degree in Victorian Literature at Queen's University, and I learned that his vast knowledge of literature was rivaled only by his passion for astronomy. We've been close friends ever since.



Leo Enright and the author pose next to the Oso Observatory's 14-inch telescope during a 2005 visit. Peter Jedicke

Over the years, Leo has cut back on his many activities. In the late 1970s, he all but ran the astronomy club at Queen's University and the Kingston Center of the Royal Astronomical Society of Canada (RASC), two independent groups that merged in 1978. The group was small, with no more than 20 members joining us at each meeting. Leo edited the newsletter, called *Regulus*, and filled it with interesting bits of news and trivia. Do you know, for example, how many days before Full Moon the Moon's light output is half of what it will be at Full Moon? The answer: just 2.5 days.

Retirement presented one happy option for Leo: He had more time for astronomy and could share it with his wife.

Leo's Oso Observatory is the result of a lifelong dream. As he was researching the history of his county, which includes Queen's University, he discovered that the subdistrict in which he lives was named Oso after the Spanish word for bear. "It might have had something to do with Ursa Major," Leo adds.

When I first met him, Leo was already designing the observatory, whose foundation consists of 43 tons of concrete. The building's telescope, then an 8-inch Celestron, had first light in 1980. Within a year, he expanded the roof and upgraded the building to house a mighty 14-inch Celestron, which remains there today.

Leo taught Latin for several years. But beginning in the 1970s, his district's interest in the classical languages declined, so he switched to English for his later years as an educator. Like many people in our generation, by the end of June 1998, retirement presented one happy option for Leo: He had more time for astronomy and could share it with his wife, Denise Sabatini. One highlight they shared on a small cruise ship in the Atlantic Ocean southeast of Nova Scotia was the August 11, 1999, total solar eclipse.

I was also on that ship, and I recall Leo's expression of utter amazement when he saw the corona reveal its full majesty just 20 minutes after sunrise. We could see the racing shadow of the Moon hurtle across the sky like the second hand of a giant celestial clock. The shadow crossed from west to east in about 50 unforgettable seconds.

I had hoped that this would be the first of many eclipse trips I'd share with Leo, but that hasn't happened. Just 4 weeks after the eclipse, he suffered a life-threatening aortic aneurysm. Thankfully, quick medical intervention saved his life. He has done well since then and has continued to enjoy astronomy. Last year he and I began an annual contribution to the RASC's *Observer's Handbook* that offers a new listing of favorite deep-sky gems.

Across space and time, Leo has looked at most of these objects through his telescope. As he continues to inspire new generations to look toward the stars, may his telescope serve him many years more.

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— Phil Harrington, *Astronomy Magazine*, August 2009

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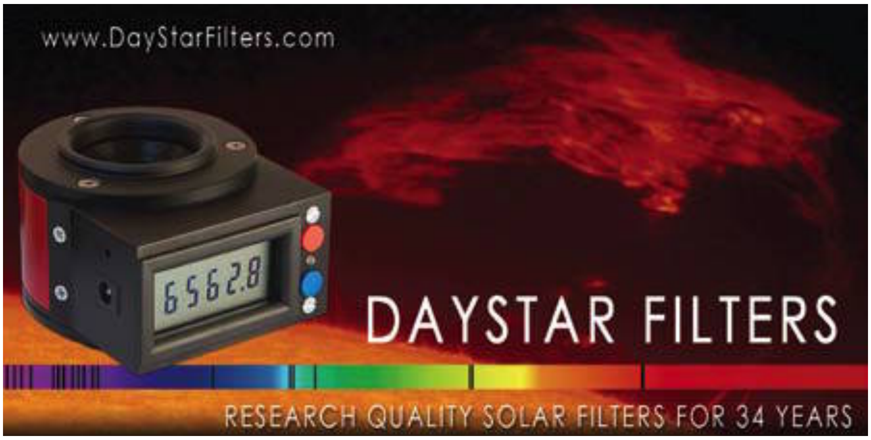

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Moon crash On June 10, the Japanese Aerospace Exploration Agency's Kaguya spacecraft slammed into the Moon after completing its nearly 2-year-long mission to study our neighbor.

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Astronomy.com/news

Astro**news**

Icy blast. Plumes of water vapor and ice shoot from the south polar region of Saturn's moon Enceladus. Two teams of scientists have reached opposite conclusions about whether an underground ocean feeds these plumes. NASA/JPL/SSI

An underground ocean for Enceladus?

Two teams of scientists studying Saturn's sixth-largest moon, Enceladus, have reached different conclusions about the existence of liquid water beneath the icy moon's surface. The idea of such a reservoir — perhaps even an ocean — first gained traction in 2005 when NASA's Cassini spacecraft discovered jets of water vapor and ice grains erupting from Enceladus' south pole.

Members of Cassini's Cosmic Dust Analyzer (CDA) team come down on the side of liquid water. The team studied the composition of ice grains in Saturn's E ring, which the moon's plumes constantly replenish, and found lots of sodium salt.

"We believe that the salty minerals deep inside Enceladus washed out from rock at the bottom of a liquid layer," says Cassini scientist Frank Postberg of the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. Postberg led the CDA team, which reported its findings in the June 25 issue of *Nature*. The team says only liquid water can dissolve the vast quantity of minerals needed to produce the observed salt.

A team of researchers using ground-based observations has a different view. University of Colorado at Boulder planetary scientist Nicholas Schneider and his colleagues observed Enceladus' plumes with the 10-meter Keck Telescope and the 4-meter Anglo-Australian Telescope. They also reported their results in the June 25 *Nature*.

Geysers tapping into an underground ocean would bring up lots of sodium, but the team found few, if any, sodium atoms in the vapor. "It would have been very exciting to support the geyser hypothesis," says Schneider, "but it is not what Mother Nature is telling us."

Scientists hope to learn more about Enceladus, its plumes, and the status of subsurface water when Cassini makes two close flybys in November. — **RICHARD TALCOTT**

22 Baby stars found at galactic center

23 NASA shoots the Moon

24 Explosion caught in the act

24 Scientists shed light on dark bursts

25 Shadows seen in rings

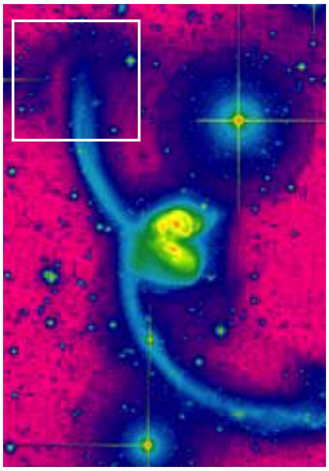
26 Sunspot cycle delayed, not gone

New debris found near galaxy collisions

A team of astronomers has observed new tidal debris associated with galactic collisions. The debris could help astronomers determine the galaxies' paths prior to colliding. The researchers, led by Jin Koda of Stony Brook University in New York, announced their findings June 9 at the American Astronomical Society meeting in Pasadena, California.

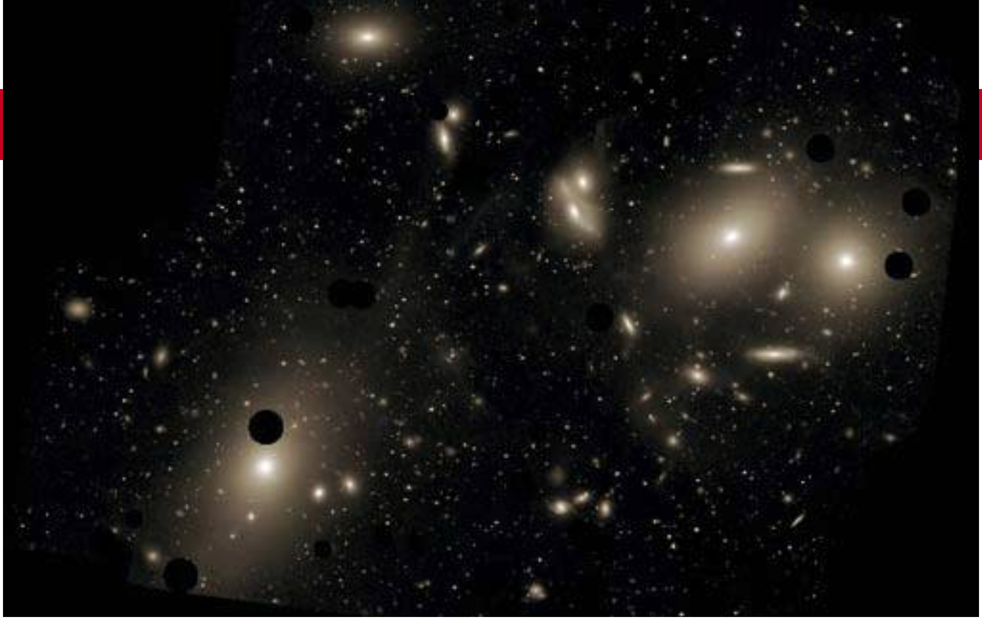
Galaxy collisions are a bit like automobile collisions: You can't tell what happened by looking at the outcome alone. So by investigating any markings related to the crash (skid marks for vehicles and tidal tails for galaxies), you can trace what happened before the collision. The team of astronomers used the 8.2-meter Subaru Telescope on Mauna Kea, Hawaii, to observe 13 galaxy collisions, including the Antennae and Mrk 231. They found that one of the Antennae's tidal tails extends twice as far as previously thought. They also observed a new tidal tail in Mrk 231.

As galaxies collide, gravity pulls stars out of their orbits to create tidal tails. In addition, gas is compressed, which initiates star formation. So astronomers study galaxy collisions to learn more about these activities. — **LIZ KRUESI**



Jin Koda/Stony Brook University

Stellar wreckage. Astronomers have discovered new tidal debris (in white square) near a tidal tail of the Antennae colliding galaxies.



Detailing a giant. Astronomers studied Messier 87 (lower left), a member of the Virgo cluster, and found its halo to be smaller than expected. The black circles show where bright foreground stars were removed from this image. This galaxy cluster lies some 50 million light-years away. ESO

Astronomers measure giant galaxy

Astronomers have measured the size of giant elliptical galaxy Messier 87 and found that the outer halo is several times smaller than expected. They also determined that M87 and a neighboring Virgo cluster galaxy, M86, are falling toward each other. The team's findings will appear in a future *Astronomy & Astrophysics*.

The international team used an instrument on the European Southern Observatory's Very Large Telescope to measure precisely the motions of planetary nebulae in M87's faint outer halo and in the intergalactic space between galaxies in the Virgo cluster. From those measurements, they could determine how far out M87's halo extends. Their results were surprising: The halo is much smaller than models of M87 predict, at some 1 million light-years wide. This is still larger than the Milky Way's halo.

One proposed explanation for the smaller halo is that another large galaxy in the Virgo cluster (M84) could have come close to M87 in the past and perturbed it. But the team needs additional observations of M87's planetary nebulae before concluding why the halo is this smaller size.

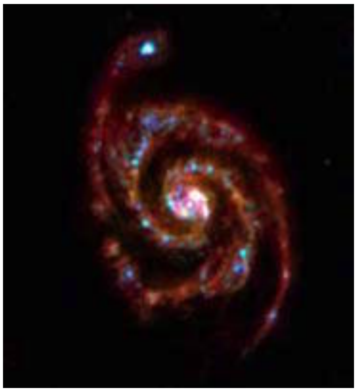
The team also found that "the Virgo cluster is still a very dynamic place, and many things will continue to shape its galaxies over the next billion years," says co-author Ortwin Gerhard of the Max Planck Institute for Extraterrestrial Physics in Germany. From their observations, they determined that the neighboring galaxies M87 and M86 are moving toward each other. — **L. K.**

Herschel opens its eye and views the Whirlpool Galaxy

On June 14, scientists with the European Space Agency (ESA) released a protective cover on the Herschel Space Observatory and snapped the infrared telescope's first images. The telescope performed better than expected and revealed details within the Whirlpool Galaxy (M51) that other infrared satellites are unable to see.

ESA launched Herschel May 14 to study the formation of stars and galaxies in the early universe and how these objects evolved. The telescope has a 3.5-meter mirror — the largest ever launched into space. Its cameras are sensitive to infrared radiation, which means it can pierce through dust.

Herschel's Photoconductor Array Camera and Spectrometer (PACS) snapped images at three different infrared wavelengths June 14 and 15. Scientists then combined those images into a detailed composite. The image is a sign of good things to come from Herschel, say project scientists. — **L. K.**



Sneak preview. During ESA's Herschel Space Observatory's first light, it snapped three infrared images that scientists combined into this detailed view of M51. Blue shows regions of warmer dust, and red shows colder.

ESA/PACS Consortium

QUICK TAKES

LESS JUICE

Astronomers announced June 9 that the diameter of Orion's red supergiant star Betelgeuse mysteriously shrank more than 15 percent during the past 15 years.

RADIOACTIVE MOON

Before it smashed into the Moon, Japan's Kaguya spacecraft and its gamma-ray spectrometer discovered the element uranium on the Moon's surface.

MID-SIZED BLACK HOLE

Most black holes weigh either a few solar masses or more than a million solar masses. But astronomers reported July 1 in *Nature* the first solid evidence for an intermediate black hole weighing 500 solar masses or more. The object lies in the distant galaxy ESO 243–49.

WINDY MOON

On June 18, scientists announced they had detected solar wind atoms reflecting off the Moon. NASA's Interstellar Boundary Explorer mission made the discovery.

A NEW ODYSSEY

Mission controllers maneuvered NASA's Mars Odyssey spacecraft into a new orbit in June. The probe now looks down on Mars in mid-afternoon, affording a better view of surface minerals.

TUNGUSKA COMET

Noctilucent clouds seen after the 1908 Tunguska impact in Siberia suggest a comet crash. Researchers showed that the clouds likely formed when the comet's icy nucleus vaporized.

PLANET SEARCH

The Space Telescope Science Institute announced June 25 that it will help the search for earthlike exoplanets by serving as a data archive for NASA's Kepler planet-hunting mission.

SOLAR SYSTEM ROOTS

Most interstellar grains trapped in the Murchison meteorite spent less than 200 million years in space. Astronomers previously thought it took 500 million years for planets and meteorites to start condensing.

ULYSSES SIGNS OFF

Ground controllers shut down the Ulysses spacecraft June 30. The joint NASA/ESA mission explored the Sun and its polar regions for more than 18 years.

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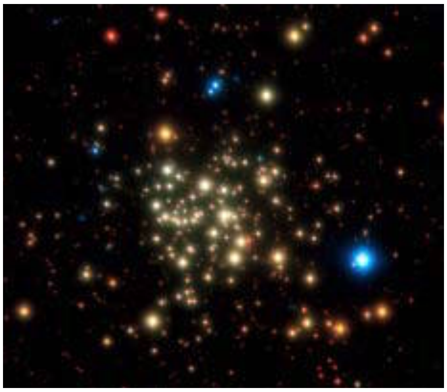
Arches Cluster more normal than thought

With thousands of stars packed into a sphere barely 3 light-years across, the Arches Cluster ranks as the densest cluster of young stars known. It manages to survive in the chaotic region near the supermassive black hole at the Milky Way's center. Surprisingly, the cluster contains the same proportion of low- and high-mass stars as more tranquil regions of the galaxy.

Steward Observatory astronomer Pablo Espinoza and his colleagues laid the Arches bare with observations using the European Southern Observatory's Very Large Telescope in Chile. Viewing the cluster at visible wavelengths is nearly impossible because huge amounts of dust lie between it and Earth. So the researchers used the NACO adaptive optics instrument, which gets sharp images at dust-penetrating near-infrared wavelengths.

The observations show that the Arches contains a total mass of about 30,000 Suns — far more than astronomers thought — packed at a density a million times greater than in the Sun's neighborhood. The most massive star weighs in at 120 solar masses.

Earlier studies suggested that the masses of the stars in the Arches followed a different pattern than they did elsewhere in the galaxy, presumably because of the extreme conditions there. No longer. "Our observations show that the masses of stars in this cluster actually do follow the same universal law," says Espinoza. The team released its results in the July issue of *Astronomy & Astrophysics*. — **R. T.**



Seeing the unseen. The densely packed Arches Cluster, which lies near the Milky Way's chaotic center, nevertheless has a star-formation history similar to other places in the galaxy. This near-infrared view penetrates the thick dust lanes between the cluster and Earth. ESO

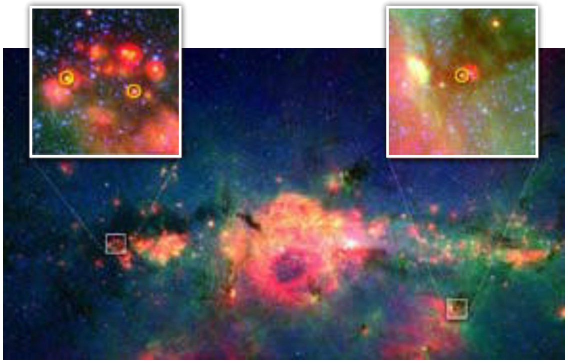
Baby stars found at galactic center

For the first time, astronomers have uncovered newborn stars at the galactic center. These three stars are less than 1 million years old and have just ignited; they're still embedded in their natal dust and gas cocoons. The astronomers announced their finding June 10 at the American Astronomical Society meeting in Pasadena, California.

The team analyzed Spitzer Space Telescope images of the galactic center. The region they looked at spans some 600 light-years — less than 1 percent of the Milky Way's diameter. However, that region contains about 10 percent of the galaxy's gas and a lot of stars and dust.

The team needed Spitzer's infrared eye to pierce through the dust and identify about 100 young star candidates. The scientists then studied each candidate object's rainbow of light (called a "spectrum") to detect the imprints of certain molecules. These spectra tell the astronomers which objects are young stars and which aren't. To determine the distance to each object, they looked at another part of the spectrum. The three newborn stars all lie near the galactic center.

Astronomers hope these findings can help them determine how baby stars form in the galactic core's hostile environment. — **L. K.**



Stellar Cradle? Astronomers have glimpsed three baby stars in the galactic center. They still don't know how stars can form in this chaotic region. NASA/JPL-Caltech/S.V. Ramírez (NExScI/Caltech)

SPACE SCIENCE UPDATE

NASA shoots the Moon

It's been 40 years since humans stepped on the Moon, and more than a decade since the United States last launched an unmanned mission to our celestial neighbor. On June 18, NASA remedied the latter situation with a clear eye toward reversing the former.

At 5:32 P.M. EDT, an Atlas V rocket lifted off from Florida's Cape Canaveral with two spacecraft aboard. The Lunar Reconnaissance Orbiter (LRO) will send back more information about the Moon than any previous mission. And the Lunar CRater Observing and Sensing Satellite (LCROSS) promises to reveal whether water ice exists in permanently shadowed craters near the Moon's polar regions.

LRO entered lunar orbit June 23. After a series of four engine burns in the 4 days after that, it settled into an elliptical orbit for its so-called commissioning phase. During the following 60 days or so, NASA checked out LRO's seven instruments to make sure they function properly.

After the check, the spacecraft will fire its engines again to reach its final orbit — a circular path that passes over the lunar poles at an altitude of approximately 31 miles (50 kilometers). That's when the real science begins. For at least a year, and probably several more, LRO will compile high-resolution three-dimensional maps of the lunar surface, survey the Moon at many wavelengths, and explore regions near the poles where the Sun never rises or sets.

In many respects, LRO follows in the footsteps of the Ranger, Lunar Orbiter, and Surveyor missions of the 1960s. Those Apollo predecessors scouted out optimal sites for the upcoming manned missions. Similarly, LRO seeks safe landing sites for the next generation of Moon explorers. But because NASA wants to build lunar outposts and leave astronauts on the surface for perhaps months at a time, LRO also will identify lunar resources and study how the radiation environment will affect humans.

Although LRO offers plenty of bang for the buck, it can't compete with LCROSS. That's because NASA will smash LCROSS into the Moon. LCROSS consists of two parts: a shepherding satellite and the Atlas V's Centaur upper stage. The two will remain attached until October as they make long, looping orbits of Earth.

If all goes according to plan, the spacecraft will hit the Moon October 9 near the lunar south pole. Nine hours before impact, at an altitude of about 54,000 miles (87,000 km), the shepherding satellite and Centaur upper stage will separate. The satellite will fire thrusters to slow down, allowing the massive Centaur (which would weigh 5,216 pounds [2,371 kilograms] on Earth) to hit first. The shepherding satellite will observe the crash and analyze the debris plume as it flies through.

Wild blue yonder. **NASA's LRO and LCROSS missions launched on a single rocket from Cape Canaveral June 18.** NASA/Bill Ingalls

Then, 4 minutes later, the 1,290-pound (586 kg) shepherding satellite will crash. Astronomers and backyard observers will view both impacts and debris plumes. Scientists will search for signs of water vapor and ice as well as hydrocarbons.

NASA will target a permanently shadowed crater near one of the Moon's poles, where ice could still exist. The space agency will decide the exact target some 30 days before impact based in part on information supplied by LRO. — **R. T.**

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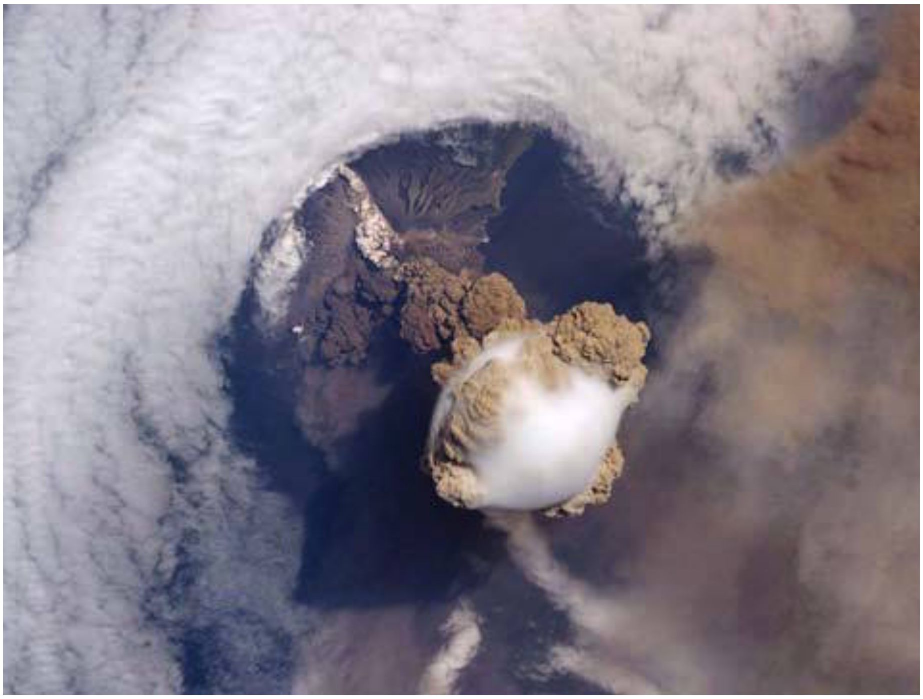


Punching bag. A plume of ash and steam from Russia's Sarychev volcano appears to be punching a hole in the cloud deck above. NASA

Explosion caught in the act

Astronauts aboard the International Space Station got a pleasant surprise June 12 when they witnessed the initial stages of an explosive volcanic eruption. The astronauts snapped several photos of Sarychev volcano as the space station flew some 220 miles (355 kilometers) overhead.

Sarychev is one of the most active volcanoes in Russia's Kuril Island chain, which lies northeast of Japan. Prior to June 12, Sarychev had not suffered an explosive eruption since 1989. Volcanologists leapt at the chance to study the eruption from above.

This early photo highlights the volcano's plume of brown ash and white steam. The smooth white cloud on top of the plume probably formed as the rapidly rising ash column cooled the air above. A lower cloud of denser gray ash is likely a pyroclastic flow — a current of hot gas and rock descending rapidly from the volcano's summit.

Scientists don't know what caused the impressive hole in the cloud deck above Sarychev. Some think the eruption's shock wave punched a hole through the clouds. Other scientists suggest that as the plume rose, surrounding air flowed down around the sides. They say this falling air warmed, and the clouds evaporated. Still others believe the hole had nothing to do with the eruption — that such atmospheric features naturally occur above islands. — **R. T.**

Scientists shed light on dark bursts

For more than a decade, astronomers have detected "dark" gamma-ray bursts (GRBs). GRBs usually are the brightest type of blast in the universe. This particular kind of GRB is seen in X-rays and gamma rays, but not in visible light. These "dark" GRBs puzzled astronomers: They weren't sure if the objects were so far away that their visible light shifted into infrared or if the objects lay in dusty galaxies.

But scientists June 8 at the American Astronomical Society meeting in Pasadena, California, announced that they have found why these GRBs aren't detected in visible light. The dark GRBs are hidden by the host galaxy's dust.

The astronomers used the Keck-I telescope in Hawaii to observe the locations of 14 dark GRBs. In 11 cases they detected a host galaxy in visible light. If the galaxies were located extremely far away, the Keck wouldn't have observed them. Hence dust patches in the galaxies must block each GRB's light. — **L. K.**

Fast shooter The European Southern Observatory and three French labs have developed a camera that can take 1,500 images per second of extremely faint objects.

Planck detectors reach their coolest

On July 3, the European Planck mission's detectors reached their final operating temperature, making the detectors the coldest objects in space. The European Space Agency satellite is now operating at one-tenth of a degree celsius above absolute zero — the coldest temperature the laws of physics allow.

Planck's goal is to observe tiny temperature fluctuations in the cosmic microwave background (CMB) — the remnant radiation from the Big Bang. The fluctuations are on the order of one-millionth of a degree, so Planck needs to be at an extremely cold ambient temperature to detect such small changes.

Planck has a passive cooling system that radiates heat into space. This system began operating right after the satellite's May 14 launch and brought its temperature to –228 °C. Three separate active coolers then brought Planck's detectors down to –273.05 °C. — **L. K.**

BRIEFCASE

Rare magnetic monster found

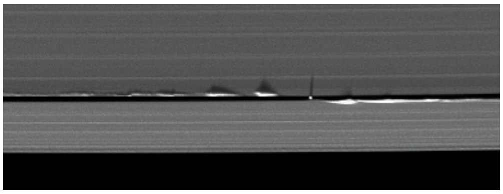
Astronomers using NASA's Swift satellite and ESA's XMM-Newton X-ray Observatory have confirmed a new magnetar — an extremely dense star with a magnetic field some 10 billion times stronger than Earth's. The magnetar's outburst arrived at Earth in August 2008 and lasted for 4 months. The finding appeared in the *Monthly Notices of the Royal Astronomical Society: Letters* published online June 12. — L. K.

Supernova as accelerator

It's long been thought that blast waves from exploding stars called supernovae accelerate particles to extreme speeds. Now scientists have evidence to back up this theory, thanks to Eveline Helder of Utrecht University in the Netherlands and colleagues, as described in the June 26 *Science*. They measured the temperature behind a supernova shock wave associated with supernova remnant RCW 86 and found that it's cooler than expected. The missing energy went toward accelerating the particles. — L. K.

Binary solar system in the making?

Astronomers from the University of Hawaii have found a binary star system where each star has its own surrounding dust disk. The material in these protoplanetary disks may coalesce to form two planetary systems. One disk contains about 70 Jupiter masses of material; the other about 20. The discovery appeared in the June 15 issue of *The Astrophysical Journal Letters*. — L. K.



NASA/JPL/SSI

Dark shadows. Shadows fall across Saturn's A ring, revealing vertical structures up to 0.9 mile (1.5 km) high in the rings. The gravity of the tiny moon Daphnis, seen within the thin Keeler Gap, creates these structures.

Shadows seen in rings

The small saturnian moon Daphnis, orbiting within Saturn's rings, creates towering vertical structures in the otherwise flat rings. NASA's Cassini spacecraft recently photographed the shadows of these structures as Saturn approached its August equinox.

At the equinox, the rings turn edge-on to the Sun. This rare geometry — it happens only twice during each 29.5-Earth-year saturnian orbit — causes any structures that lie just outside the ring plane to cast long shadows across the rings. Cassini's cameras easily capture these shadows.

The lengths of the observed shadows indicate that these structures reach as high as 0.9 mile (1.5 kilometers) above the rings. This is as much as 150 times higher than the rings' thickness. Saturn's main rings — dubbed A, B, and C — measure only about 33 feet (10 meters) thick.

John Weiss of the Space Science Institute in Boulder, Colorado, and his colleagues showed how gravitational effects from the 5-mile-wide (8 km) moon Daphnis create these structures. The small moon orbits inside the 26-mile-wide (42 km) Keeler Gap in the outer A ring. The team published its results in the July *Astronomical Journal*.

The researchers found that Daphnis, which has an elliptical orbit inclined slightly to the ring plane, can raise vertical ring structures when it comes close to the gap's edges. And that's what Cassini found. "We thought that this vertical structure was pretty neat when we first saw it in our simulations," says Weiss. "But it's a million times cooler to have your theory supported by such gorgeous images." — **R. T.**

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SOHO (ESA/NASA)

Spotted Sun. The latest solar cycle has gotten off to a slow start. In this image from early July, a small sunspot group lies near the Sun's southeastern limb.

Sunspot cycle delayed, not gone

A sluggish jet stream beneath the Sun's photospheric surface appears to be the culprit behind the current minimum in solar activity. But this jet stream is on the move now, and activity — sunspots, flares, and coronal mass ejections — has started to rise.

The lull in solar activity has been unusually long and deep. National Solar Observatory (NSO) scientists Rachel Howe and Frank Hill think they know why. Using NSO's Global Oscillation Network Group (GONG), they detected and tracked an east-to-west jet stream located 600 to 4,000 miles (1,000 to 7,000 kilometers) below the Sun's surface.

The Sun generates new jet streams near its poles every 11 years. The streams migrate to the equator during a 17-year period. When the jet streams reach a critical latitude of 22°, the Sun typically starts to produce sunspots.

Howe and Hill found that the stream associated with the new solar cycle has taken 3 years to cover 10° of latitude; the stream involved in the previous cycle took only 2 years to cover the same range. The researchers concluded that the extended solar minimum likely reflects the stream's slower migration.

"It is exciting to see that just as this sluggish stream reaches the usual active latitude of 22°, a year late, we finally begin to see new groups of sunspots emerging," says Hill. The scientists announced their findings June 17 at a meeting of the American Astronomical Society's Solar Physics Division in Boulder, Colorado. — **R. T.**

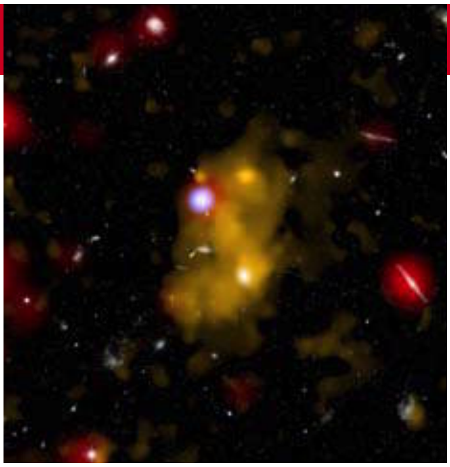
Black hole radiation lights gas blobs

For some 10 years, astronomers have puzzled over what makes massive hydrogen gas blobs in the early universe glow in optical light. New observations with the Chandra X-ray Observatory and the Spitzer Space Telescope support the idea that radiation from supermassive black holes ram into the nearby gas and light up the blobs. This finding appeared in the July 10 issue of *The Astrophysical Journal*.

Astronomers used Chandra to observe a region known as SSA22 for about 5 days. In this region they found 29 blobs, some up to 500,000 light-years across. They date back to about 2 billion years after the Big Bang. Five of the objects showed a bright source of X-ray emission — a telltale sign of a supermassive black hole. Another three showed possible evidence of black holes.

The scientists also looked at these objects with Spitzer to see through the dust and view star formation. Using these observations, scientists concluded that both the black hole's radiation and emission released during star formation are illuminating the blob.

In addition, the radiation is "pushing back on the infalling gas to prevent further growth," says co-author Bret Lehmer of Durham University in England. The black holes are essentially slowing down galaxy growth. Within about 1 billion years, the gas that didn't become stars likely will be blown away from the galaxy. — **L. K.**



X-ray (NASA/CXC/Durham Univ./D.Alexander et al.); Optical (NASA/ESA/STScI/IoA/S.Chapman et al.); Lyman-alpha Optical (NAOJ/Subaru/Tohoku Univ./T.Hayashino et al.); Infrared (NASA/JPL-Caltech/Durham Univ./J.Geach et al.)

Ginormous blob. Radiation from a supermassive black hole (X-rays in blue) and forming stars (infrared in red) are lighting up a massive hydrogen blob (yellow) in the early universe.

25 years ago in *Astronomy*

October 1984

In the October 1984 issue of *Astronomy*, freelance writer Ken McBride discussed the searches that scanned the sky for signs of planets orbiting other suns in "Looking for Extrasolar Planets."

It would be 7 years before astronomers discovered the first planet outside of our solar system. That planet orbits a highly magnetized compact star called a pulsar. We're now up to 350 extrasolar planets and counting. The Kepler satellite, launched March 6, promises to dramatically increase that number — and hopefully find earthlike planets around other stars.

McBride wrote that "when our new telescopes are finally ready to unveil the galaxy's worlds, we might do well to expect a few surprises." How right he was.

10 years ago in *Astronomy*

Astronomy
THE GIANTS

October 1999

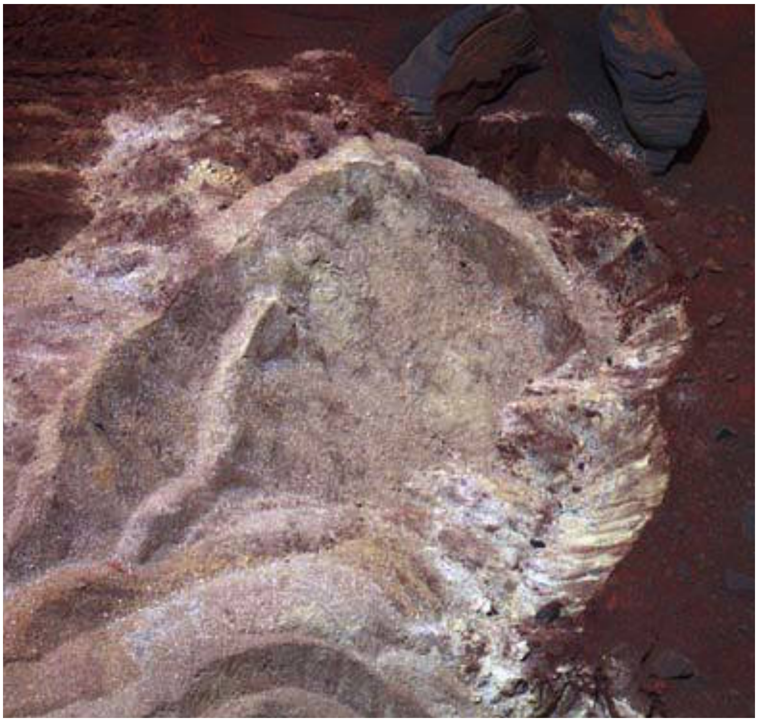
The October 1999 issue of *Astronomy* featured a review of one of the newest findings in science at that time: dark energy. Renowned journalist James Glanz wrote about the discovery — the adventure leading up to it and how the scientific community reacted — in "Accelerating the cosmos." And he did it as a behind-the-scenes review of a journalist covering this important discovery.

During the past 10 years, cosmologists have observed many more type Ia supernovae — the standardized exploding stars that in the 1990s gave the first hints of dark energy. Recent observations of galaxy clusters and how they evolve over time with the Chandra X-ray Observatory have also given cosmologists another line of evidence to follow.

Still, astronomers don't know what powers dark energy. But proposed dark energy satellites may come online in the next decade, which will likely provide clues to one of the biggest discoveries in astronomy. — **L. K.**

Flare for the dramatic

Gamma-ray and radio astronomers have pinpointed where the active galaxy M87 produces its brilliant flares. The spot lies less than 0.1 light-year from the galaxy's supermassive black hole.



NASA/JPL-Caltech/Cornell University

Loose soil. The Mars Spirit rover took this composite image of "Troy" about a week before the rover got stuck in this same soil. The soil colors in the image have been stretched. The rocks in the upper right are about 4 inches (10 centimeters) long.

Spirit doing science while stuck

NASA's Mars rover Spirit has been lodged in the soft martian soil since early May. Around that time wind cleaned the dust off the rover's solar panels, giving an energy boost to Spirit. With the added charge, Spirit is investigating its current surroundings. "If your rover is going to get bogged down, it's nice to have it be at a location so scientifically interesting," says team member Richard Moddis of NASA's Johnson Space Center in Houston. On June 25, the team released an image of the soft soil near the stuck rover.

Scientists have dubbed that interesting location "Troy." It sits near the low plateau called Home Plate, which is some 2 miles (3.2 kilometers) from Spirit's landing site. Troy is made up of numerous layers of soil with differing colors. "The layers have basaltic sand, sulfate-rich sand, and areas with the addition of silica-rich materials," says team member Ray Arvidson of Washington University in St. Louis.

Spirit's new energy has enabled "full use of all of the rover's science instruments," says Moddis. The explorer is using its robotic arm to investigate the nearby soil. Scientists aren't sure if this material formed through more recent processes or if it existed billions of years ago and then recently was disturbed by winds.

Since Spirit got stuck, scientists have created a soil mix to mimic that at Troy. They're using a test rover in the soil to find a way to maneuver Spirit out of its sticky situation. — **L. K.**

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Galactic architecture

How we **mapped**

After a centuries-long mystery, scientists now understand our galaxy's spiral shape. But there's more to unravel. **by Liz Kruesi**

Our home galaxy's most characteristic trait is its spiral structure. While the spiral arms may seem obvious to us now, this hasn't always been the case. Because we're embedded in the Milky Way, it's much harder to know what the structure looks like. We can observe other magnificent spiral galaxies — M51 and M101, for example — but we're looking at those face-on. When you're in the maze, it's much more difficult to understand its form.

So how did astronomers disentangle the Milky Way's structure? How did they map our galaxy's spiral arms and central bar? Both astronomers' persistence and detection methods, which have utilized a large portion of the electromagnetic spectrum, were crucial to the breakthrough. By observing different types of radiation — optical, radio, and infrared — researchers could pick out different features of the arms and piece them together for the whole picture.

A rotating disk

Galactic observations began with the most familiar form of radiation: visible light. In the 1780s, William Herschel counted the number of stars in different regions of the night sky to estimate the galaxy's shape and size. In doing so, he provided the first evidence that the galaxy is a stellar system shaped like a flat disk. He noticed that there are far more stars along that

the **Milky Way**

The Milky Way's center glows in infrared radiation. The galaxy's dust and other absorbing material block visible light, so astronomers must observe in infrared to pierce through the dust and view the Milky Way's secrets. NASA/JPL-Caltech

starry path in the sky — the Milky Way band — than near the poles. So he saw that path as the galaxy's disk.

He also observed that "nebulae" (the fuzzy patches of light in the sky) aren't distributed uniformly in all directions: Their number increases as one looks away from the galaxy's plane. He didn't know it then, but the reason there appear to be more nebulae away from the disk is that the plane has more dust, stars, and gas that obscure our vision.

Another big step forward came more than a century later when astronomers began to discover that the disk rotates around a central region. The fact that the galaxy has a flattened disk suggests it's rotating. Think of pizza dough thrown in the air. What starts out bulky ends up thinning into a flattened disk because of rotation. Conversely, large orbiting star systems called globular clusters are arranged somewhat spherically, which suggests that as a whole they don't rotate with respect to the galactic center. While individual globulars have random motions, the system doesn't rotate.

It wasn't until 1927 that astronomers found proof of the Milky Way's rotation. Dutch astronomer Jan Oort, building on Swedish astronomer Bertil Lindblad's theory, explained the relative motions of nearby stars as an effect of galactic rotation.

So the galactic disk is rotating, but where is its center? When observing the plane in visible light, the

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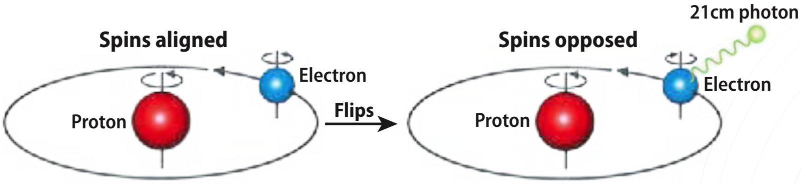
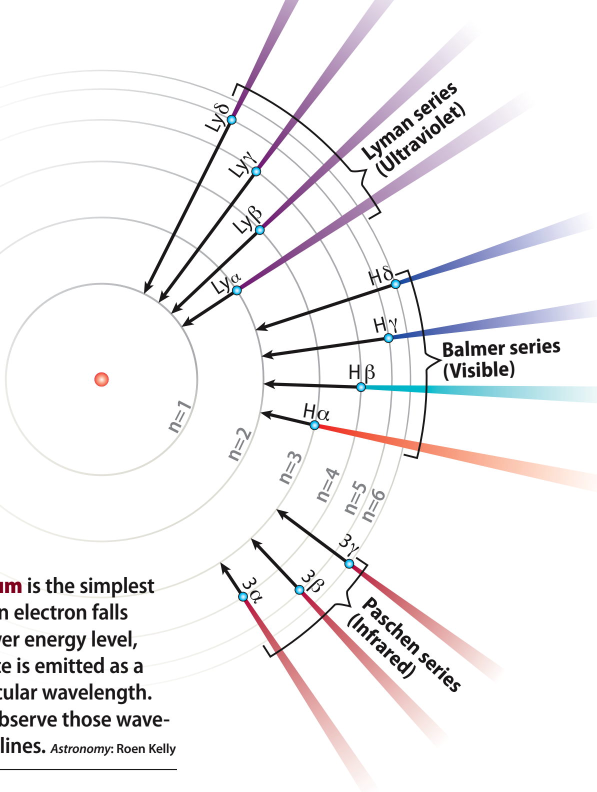
Reading hydrogen's signature



At neutral hydrogen's lowest energy level — n=1 in the diagram to the right — the electron and proton both have a spin. This spin is analogous to Earth and the Sun spinning separately as Earth rotates around the Sun. The electron's spin can either align with the proton's spin (left) or oppose it (right). As the electron's spin flips from the higher energy state to the lower, it emits a 21-centimeter wavelength photon. *Astronomy*: Roen Kelly



Hydrogen's spectrum is the simplest of all elements. As an electron falls from a higher to lower energy level, the energy difference is emitted as a photon with a particular wavelength. Astronomers then observe those wavelengths as emission lines. *Astronomy*: Roen Kelly

part that's toward Sagittarius is brighter than other parts. This implies that the center is in Sagittarius' direction. Additional evidence came by way of American astronomer Harlow Shapley in 1918. He determined the locations and distances to 69 globular clusters. Assuming they're arranged in a roughly spherical distribution, he found their average center of motion is just south of the Milky Way's plane. And because the richest concentration lies in the direction of Sagittarius, he assumed (correctly) that the center lies there. Many studies throughout the following decades proved this finding and also added to it: Our Sun is about 26,000 light-years from the center.

Tracing the arms

Prior to the advent of stellar mapping techniques, astronomers suspected the Milky Way is a spiral because of two main facts: The galactic system is flat, and they knew that hot young blue stars exist. From observations of other spiral galaxies, they saw blue stars within star-forming regions speckling the arms.

Astronomers believe arms form because of spiral compression waves, or "density waves," moving through the disk. These waves move at a different speed compared with the material in the plane. So stars, gas, and dust compress as they enter a region of higher density (the entrance to the arm), in the same way there's a traffic jam on the expressway. As this compression happens, it initiates star formation. After the material gets past the entrance point, the density falls.

In the late 1940s, German-born American astronomer Walter Baade and American astronomer Nicholas Mayall studied M31's spiral structure and found that young blue stars and their surrounding gas clouds, or "emission nebulae," trace the arms. So astronomers began looking for such objects.

Ultraviolet radiation from hot young blue stars within hydrogen gas clouds ionizes the hydrogen. Ionized hydrogen (HII) emits characteristic colors, or wavelengths. Astronomers then look for these wavelengths to map the HII.

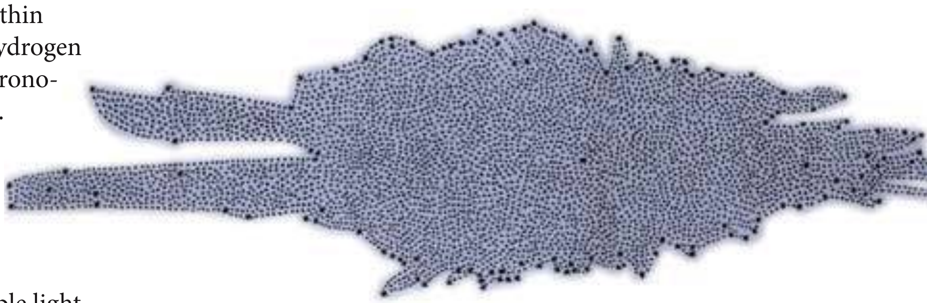
In 1951, astronomers gained direct evidence of the galaxy's spiral arms. American astronomers William W. Morgan, Stewart Sharpless, and Donald Osterbrock observed two parallel strips of HII regions, which correspond to spiral arms.

Observing emission nebulae and blue stars in visible light worked well for the galaxy's nearby structure. But as astronomers found out, the galactic plane has gas and dust that obstructs light. They would have to find another tool to observe more distant portions of the galaxy.

Something's out there

In 1930, Swiss-born American astronomer Robert Trumpler proved that dust and gas affect starlight. He observed some 100 "galactic clusters" of young stars and calculated their distances two ways. First, he assumed the clusters had the same diameter, and that would mean that the smaller a cluster appeared, the farther away it was. Second, he compared the observed luminosities of certain stars with their intrinsic luminosities (estimated from their spectral types). The dimmer the observed brightness, he concluded, the farther away the cluster was. The data from both methods should have matched if the galaxy didn't contain any absorbing material. But they didn't line up, which meant gas and dust were obstructing light in the plane.

The gas and dust, called the interstellar medium (ISM), absorbs and scatters — and therefore dims and reddens — starlight. How does this happen? Visible light's wavelength is similar in scale to dust particles and gas molecules. So the ISM scatters visible light. Longer wavelengths (such as radio and



William Herschel counted all stars visible in select regions to create his map of our galaxy. He placed the Sun (shown as the larger "star") near the center because astronomers at the time didn't know of the dust and other material in the Milky Way's plane. Linda Hall Library of Science, Engineering, and Technology

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Liz Kruesi *is an associate editor of* Astronomy.

Dust in the galaxy's disk severely hampers our view. It wasn't until 1930 that astronomers realized gas and dust affect starlight. Tunç Tezel

infrared), on the other hand, can make it through the ISM unimpeded. Naturally, the next step was to move away from visible mapping techniques.

The radio revolution

In 1944, Dutch astronomer Hendrik van de Hulst predicted that neutral hydrogen atoms in galactic gas clouds emit radiation at a characteristic wavelength. This sharp emission lies at a wavelength of 8.3 inches (21 centimeters). So astronomers looked for this "21cm line" to chart the location of hydrogen in the disk, assuming the hydrogen would map out the spiral arms.

To map in radio emission, scientists must decide on a general section of the sky to observe (say with dimensions of 20° by 20°). They then pick a few specific locations and measure (in that wavelength) along that line of sight — gathering information about everything that the line intersects.

Remember that the galactic disk is rotating, so every hydrogen cloud they observe is moving, and therefore its emission lines shift along the electromagnetic spectrum. For a patch moving toward the observer, the detected wavelength will be smaller because the wavelengths are condensed. If it's moving away from the observer, the wavelengths will stretch and therefore be longer. This is called the Doppler effect. You likely have encountered this as the sound of a train moving away from or toward you. As the train moves toward you, the pitch you hear is higher (shorter wavelength) than what you hear when it moves away from you (longer wavelength).

By comparing the measured emission line with the standard 21cm line, astronomers can determine at what velocities the hydrogen clouds are moving. The 21cm line doesn't provide an actual distance. That must be calculated using the detected velocity. In our galaxy, just like any rotating, flat object, an object's speed depends on its distance from the center.

Astronomers measure the speeds of stars in other galaxies and compare those versus the stars' distances to create "rotation curves." They also create such a plot for the Milky Way, except it's more difficult when you're within the galaxy.

In addition to knowing how velocity varies with distance from the galactic center, astronomers must know how far the Sun is from the center. Remember, it's about 26,000 light-years distant.

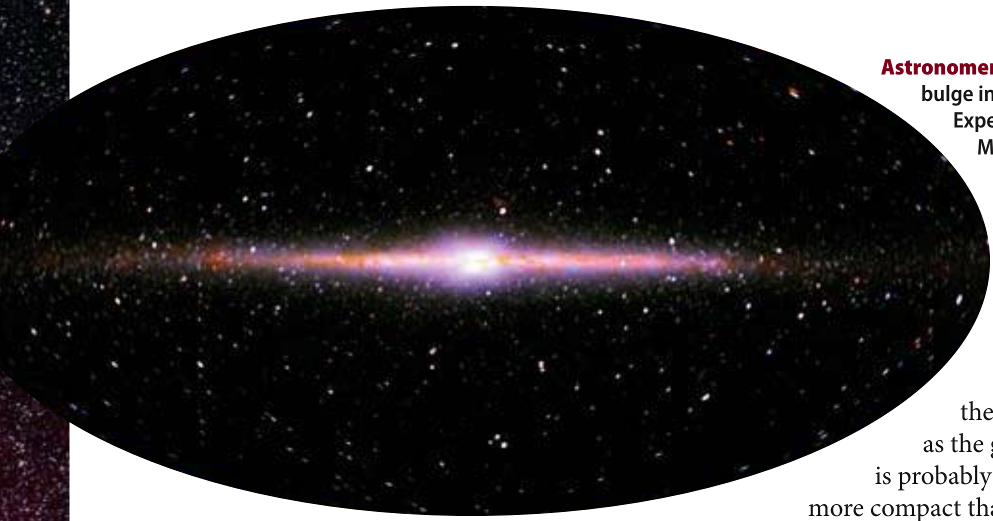
So each cloud along the line-of-sight measurement will be at a different distance from the center and therefore traveling at a different speed. The scientists see multiple sharp emission lines near 21cm, but slightly Doppler-shifted.

They have the clouds' velocities, and by comparing the velocities to the rotation curve, the astronomers can determine the clouds' distances from the center. Now the astronomers can plot the clouds' locations. And it turns out the clouds trace spiral arms. In 1953, Oort and van de Hulst were the first to publish results from a 21cm radio survey.

Like any galaxy mapping survey, astronomers have to take 21cm observations with a grain of salt. Some galactic sections

M51: Bob and Janice Fera; M101: John Smith

Compared to the Milky Way, M51 (top) is a more compact grand design spiral and M101 (bottom) is a looser spiral. Astronomers have used many mapping techniques to determine our galaxy's structure.



Astronomers obtained the first image of our galaxy's central bulge in infrared in 1990. The Diffuse Infrared Background Experiment (DIRBE) mapped stellar emission along the Milky Way's plane in three different infrared wavelengths to create this composite. The COBE Project/DIRBE/NASA

deviate from circular motions; some move randomly. By combining different methods, astronomers can piece together a more accurate structure map.

By the late 1950s, astronomers knew that the Milky Way has several arms that are trailing as the galaxy rotates. They also knew that our galaxy is probably not a compact grand design like M51, but it's more compact than M101 (see galaxy images on page 31).

Roughly half the hydrogen in the ISM is not atomic (single atoms of hydrogen), but molecular H_2 (meaning that it's made up of two hydrogen atoms). H_2 emits weak radio wavelengths. However, carbon monoxide (CO) emits strongly in radio and shows up in the same locations as H_2. These molecules also appear in a relatively consistent ratio. So astronomers can chart H_2 by tracking CO's emission lines.

In the 1970s, scientists began mapping CO, and therefore H_2, regions. They used different radio techniques to piece together a map of the galaxy's spiral structure.

However, even with those methods they struggled to understand the structure within the galaxy's inner regions. In the late 1950s, astronomers observed curious motions of the arms close to the core. They noticed that the gas didn't simply rotate around the center (like the rest of the galaxy) — it also moved away from core. They called it the "3 kiloparsec expanding arm." But what created this arm?

Some suggested our galaxy might harbor a central bar extending some 10,000 light-years (3 kpc) from the center on each side. At the bar's ends could be a ring structure or spiral arms. Determining the structure of our galaxy's center would have to wait until the 1990s when infrared satellites were lofted into space.

Filling out the picture

Researchers continued their multiwavelength assault of the Milky Way. They soon turned to infrared — higher energy (shorter wavelength) than radio but lower energy (longer wavelength) than visible light. Because infrared passes unimpeded through galactic dust, astronomers could observe the galactic core through the dusty haze. Although astronomers observed the Milky Way in infrared as early as the 1950s, they found little success because Earth's atmosphere blocks most of the infrared spectrum.

NASA's Cosmic Background Explorer (COBE) fixed this problem by carrying into space the infrared detector Diffuse Infrared Background Experiment (DIRBE). In 1990, DIRBE took the first near-infrared image of our galaxy's central bulge. The view was impressive — and the edge-on image looked just like other spiral galaxies' profiles.

Additional infrared surveys have created sharper images of our galactic plane and the bulge. But probably more importantly, astronomers now can see through the dust and study the motions of the stars near the core.

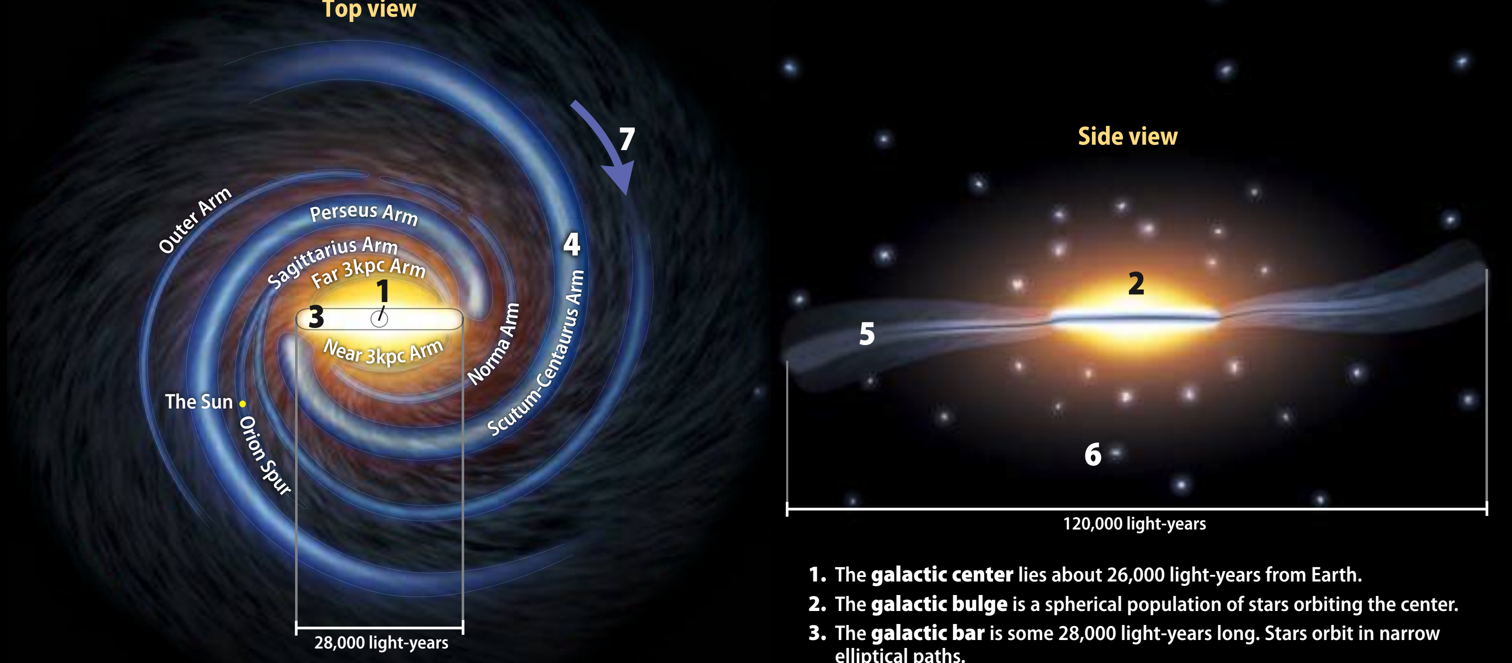
Finding the unseeable

In the 1970s, while astronomers were mapping the galaxy's spiral structure, they happened upon a mystery. Imagine the surprise when the stars in the outer parts of the Milky Way didn't do what scientists predicted. They expected the velocities to reach a maximum and then decrease farther from the center. But instead the stars' speeds reach a maximum and then plateau. With velocities of this magnitude at the outer edge of galaxies, the stars should fling out of their orbits. But they don't. So some sort of mass that we can't see must hold these outer stars in their paths.

The Milky Way Galaxy that astronomers were so familiar with (which included a disk, core, and spherical halo) represented only part of the structure. Another huge halo of invisible matter, called dark matter, surrounds our familiar galaxy. That halo is some 5 times wider than the luminous part of our galaxy and about 10 times more massive. Today's surveys still haven't given astronomers much new information about this odd invisible matter. — *L. K.*

The Milky Way Galaxy is embedded in a dark matter halo. This simulation shows the dark matter density, where brighter areas correlate to higher density. Diemand et al.

Our galaxy — a primer



After centuries of research, astronomers have a pretty good idea of what our galaxy's structure looks like. They know it has a central bar and four spiral arms, where two appear more prominent than the others. (The Outer arm is a portion of the Norma arm.) The disk also seems to have a slight warp as one looks toward the edges. *Astronomy*: Roen Kelly

1. The **galactic center** lies about 26,000 light-years from Earth.
2. The **galactic bulge** is a spherical population of stars orbiting the center.
3. The **galactic bar** is some 28,000 light-years long. Stars orbit in narrow elliptical paths.
4. **Spiral arms** are regions of higher density and compression of gas. This compression triggers star formation.
5. The **galactic disk** contains most of the galaxy's stars. It's some 120,000 light-years wide.
6. **Globular clusters** orbit the center within the spherical halo.
7. **Rotation of material** helps maintain the galaxy's disk shape.

Remember that in the 1950s some astronomers noticed that the gas didn't move as expected within a radius of about 10,000 light-years (3 kpc). Infrared studies have the ability to explain what caused those motions.

In the 1990s, scientists were analyzing infrared studies of the galactic center from balloons and DIRBE. They observed the bulge as elongated and slightly "thicker" on one side — thus implying a bar that is angled to us (as it rotates around the center).

A more recent study nailed down the bar's existence. In 2005, the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) survey observed further into the mid-infrared wavelengths and catalogued some 30 million sources to accurately map the galactic center. GLIMPSE astronomers observed a greater star count on one side, which implied a bar. They also determined that the bar has a length of about 28,000 light-years. Compare that to the Sun's distance from the galactic center (26,000 light-years).

So what is a central bar? It's a large grouping of stars moving in elongated elliptical orbits around the center. Two spiral arms — the Scutum-Centaurus and Perseus — attach to the ends of the bar. Two other arms likely start from the long sides of the bar.

And here's the kicker. For decades, astronomers believed our galaxy has four major arms — Perseus, Sagittarius, Scutum-Centaurus, and Norma — along with a few spurs (such as the Orion Spur, where we live). But in 2008, the GLIMPSE survey made another big discovery: Our galaxy may have two major arms and two minor arms. Scutum-Centaurus and Perseus appear rich in gas, young stars, and old stars. But Sagittarius and Norma seem to be mostly gas sparsely sprinkled with stars.

ESO

M83 is a barred spiral galaxy, like the Milky Way. Astronomers think that if we could view our home galaxy from above, it might look something like M83.

Astronomers have used radio, infrared, and visible light to come up with a fairly detailed map of the galaxy. The disk is about 120,000 light-years wide, with a central bar 28,000 light-years long. We are 26,000 light-years out from the core and move at 140 miles per second (220 km/s). But there are still a lot of mysteries — the composition of dark matter and how many arms are there, just to name a couple. Astronomers won't lack research topics anytime soon.

Our galaxy is one of many; how and when did astronomers determine this? Visit www.Astronomy.com/toc to find out.

Fourth rock from the Sun

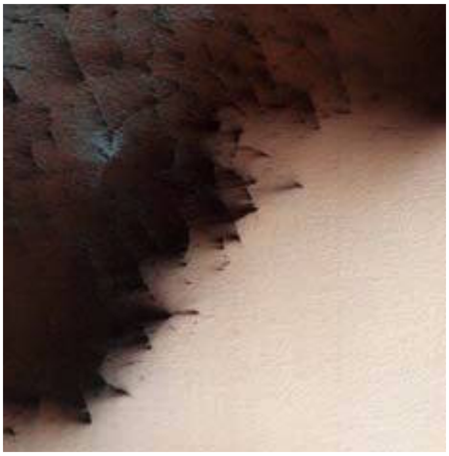
Seeking ground truth

As the sky grew darker in mid-March, mission planners worried that the end might be near. After all, the twin Mars rovers, Spirit and Opportunity, had long been living on borrowed time. Originally designed for 3-month missions, both were now into their sixth year of operation.

The martian dust storm started in the Hellas Basin, a giant impact feature in the southern hemisphere. The basin couldn't hold the storm for long. By mid-April, the storm was spreading northward. The airborne dust obscured the Sun, and the rovers — which use solar panels to convert sunlight to electricity — started to lose power. Spirit's power dropped by 20 percent and Opportunity's by 30 percent.

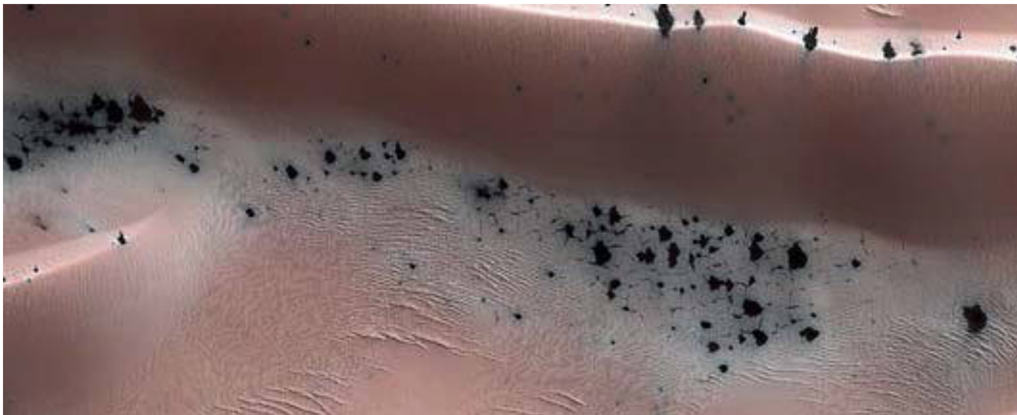
Such storms typically begin when Mars lies near the Sun (closest approach came April 21) and springtime weather warms the southern hemisphere (the solstice arrived May 21). At first, planetary scientists thought the tempest might go global. But as quickly as the gale billowed up, it died down. By mid-May, sunlight once again streamed through the thin martian atmosphere. The rovers recovered, set to explore another day, and perhaps much longer.

Yet the rovers' biggest discovery — that liquid water once flowed across the martian surface — lies well in the past. The focus of Mars exploration has now shifted to the three spacecraft orbiting the Red Planet. NASA's Mars Reconnaissance Orbiter (MRO), NASA's Mars Odyssey, and the European Space



Dark dust fans out over Mars' seasonal polar cap during southern spring. As the Sun's increasing warmth thaws this frozen carbon dioxide, the ice turns directly to gas. Gas erupts from beneath the ice layer and carries dust with it, which creates the dark patterns seen here. NASA/JPL/University of Arizona

Deep in the southern hemisphere, sand dunes fill part of the 34-mile-wide (55 km) Richardson Crater. Although the sand dunes themselves are dark, about 1 to 2 feet (0.5m) of bright carbon dioxide frost covers them in winter. In this springtime view, the frost has disappeared in a few exposed areas. NASA/JPL/University of Arizona



Under the watchful eye of five spacecraft, the Red Planet's surface reveals weather and climate patterns and the complex history of water and ice.

by Richard Talcott

on Mars

Opportunity reveals the true colors of Mars in this panorama taken in November 2008. The rover traveled 8.46 miles (13.6 km) over nearly 5 years to reach this vantage. Opportunity spent 5 weeks here while the Sun lay between Earth and Mars. NASA/JPL/Cornell University

Agency's Mars Express have charted changes in weather and climate and discovered ice just beneath the surface. When combined with the findings of NASA's 2008 Phoenix Mars Lander, the new discoveries paint a picture of a planet with a dynamic past and present.

Changes on the ice cap

With spring in full swing across Mars' southern hemisphere in early 2009, remarkable changes took place in the south polar cap. Unlike Earth, each martian pole has both a permanent ice cap and a seasonal cap. The seasonal cap forms during winter when carbon dioxide freezes out of the atmosphere onto the surface. This frost eventually builds up into a layer of frozen carbon dioxide (dry ice) approximately 3 feet (1 meter) deep.

As the Sun climbs higher in the sky and temperatures warm during martian spring, the carbon dioxide thaws directly from ice to gas. The seasonal polar cap thins from both top and bottom. Gas trapped beneath the cap builds up pressure and eventually finds a weak spot where it erupts to the surface.

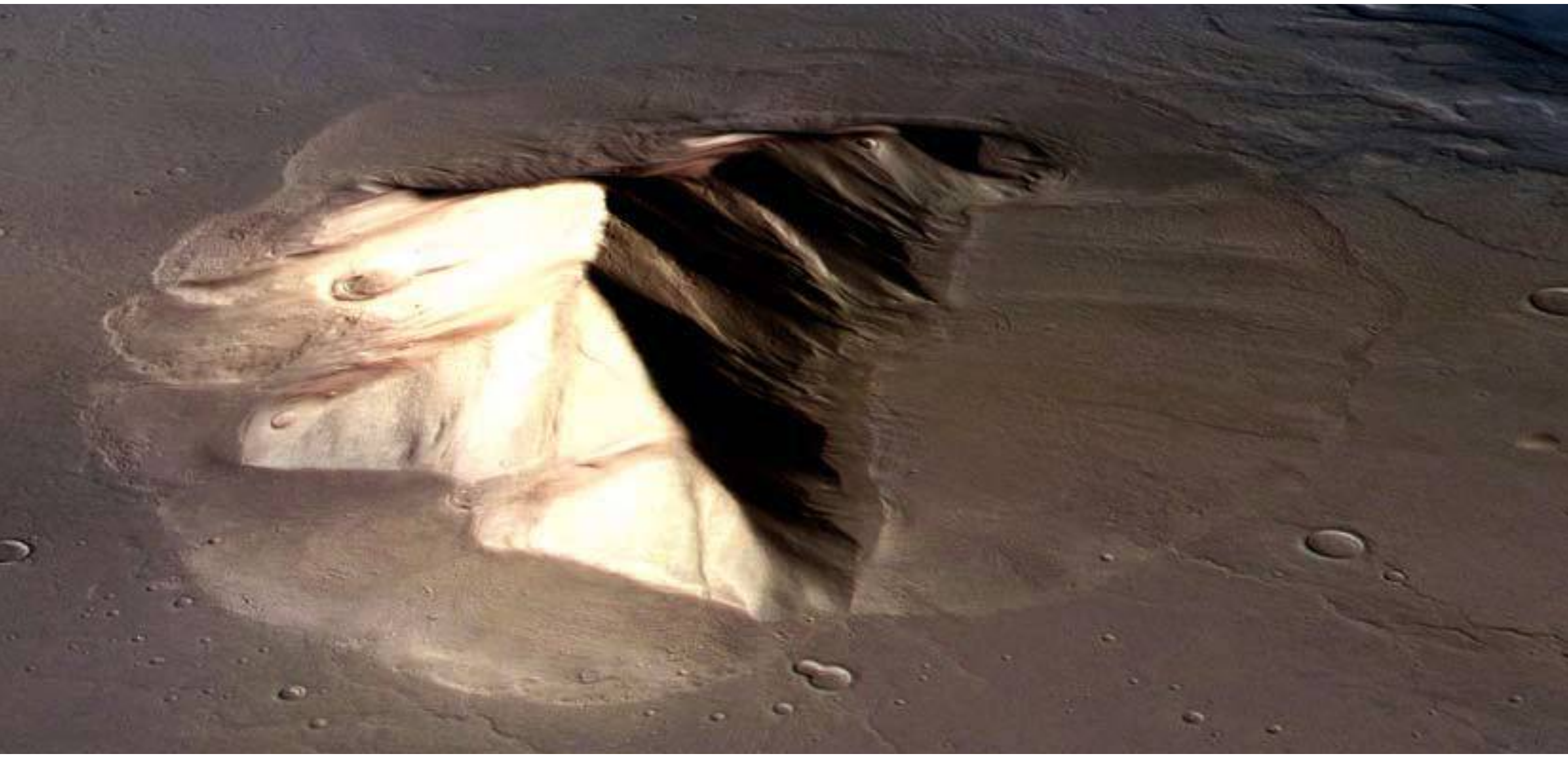
As it does so, it often brings along dust that gets deposited on the surface. In some locations, the dark material forms patterns that look like spiders. In others, they leave behind fan-shaped deposits. And in still other spots, the thinning polar cap simply reveals the dark surface below while brilliant frost continues to coat nearby regions.

MRO's High Resolution Imaging Science Experiment (HiRISE) captured all these features during this year's southern spring. Some planetary scientists study these images to learn more about the seasonal cycles of freezing and thawing. Others simply wait for the frost to disappear so they can examine the underlying terrain. This is the second southern spring to fall under MRO's watchful gaze since the spacecraft arrived at Mars in 2006.

A watery grave

Carbon dioxide ice excites Mars scientists, but water ice really gets their attention. In the past several months, researchers have discovered vast deposits of frozen water lurking just beneath the martian surface. Even more enticing: The ice occurs much closer to the equator than any previously identified.

Scientists used MRO's Shallow Radar (SHARAD) instrument to peer below the



A debris apron surrounds this mountain in Mars' eastern Hellas region. MRO's Shallow Radar instrument detected large deposits of water ice beneath similar deposits in this area. This perspective view, created from Mars Express topographic data, spans 39 miles (63 km). Ernst Hauber (DLR)

blankets of rocky debris that protect the glaciers from solar heat. (Any exposed ice would vaporize quickly in Mars' thin atmosphere.)

Two research teams examined "aprons" — gently sloping areas of rocky deposits that appear at the bases of mountains or cliffs. John Holt of the University of Texas at Austin led a team that studied aprons in the vicinity of the Hellas Basin. The researchers found buried glaciers dozens of miles long and up to a half-mile thick. A second team, led by Jeffrey Plaut of NASA's Jet Propulsion Laboratory (JPL), targeted aprons in the northern hemisphere with similar results.

Scientists have known about the aprons since the Viking missions in the 1970s. Yet no one knew whether these features are flows of water ice or of rocky debris lubricated by small amounts of ice. SHARAD told the tale. The radar echoes passed through the aprons and reflected off the surface beneath with almost no signal loss. There were no reflections from rocky debris inside the deposits, so the aprons must be nearly pure water ice.

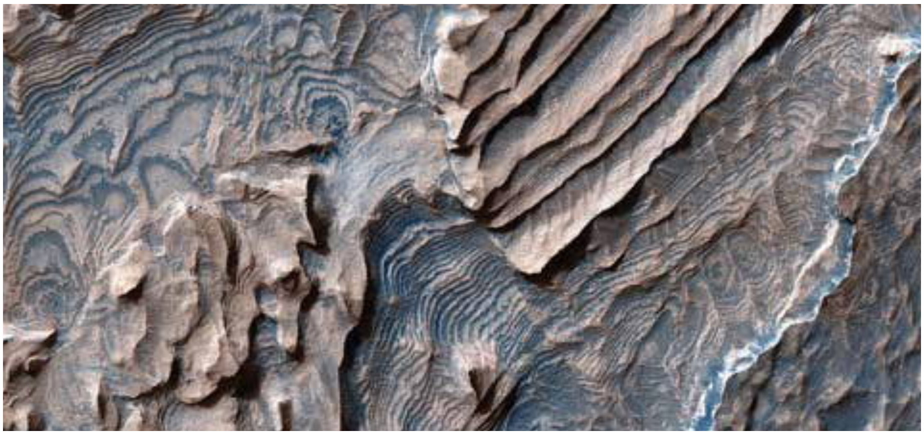
"Altogether, these glaciers almost certainly represent the largest reservoir of water ice on Mars that is not in the polar caps," says Holt. The scientists suspect the glaciers may be remnants from an ice sheet that blanketed the mid-latitudes during a past ice age. The ice could be a source of water for future Mars exploration. It also reinforces the idea that Mars may once have had enough water for life to gain a toehold.

Layers reveal ancient climate

Although the ice tells scientists something about Mars' past, climate cycles lasting millions of years etched their signatures into rock elsewhere on the planet. HiRISE discovered a record of rhythmic patterns in the sedimentary rock layers of four craters located in the Arabia Terra region.

Layers of similar thickness repeat up to hundreds of times in some of the craters. And in one, Becquerel, bundles of a 10-layer pattern repeat at least 10 times. This repetition seems to correspond to changes in the tilt of Mars' rotation axis, which goes through a similar cycle.

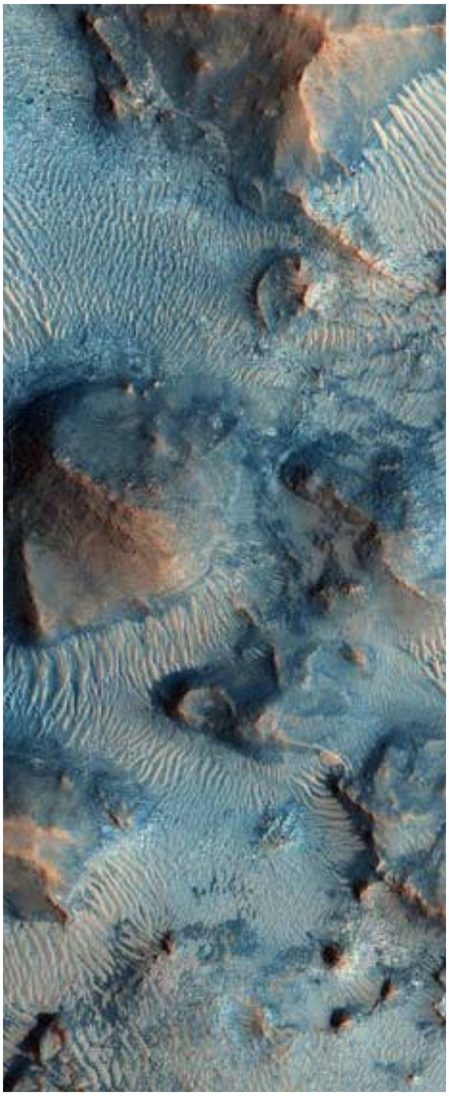
The discovery comes from HiRISE stereo images. By looking at the same



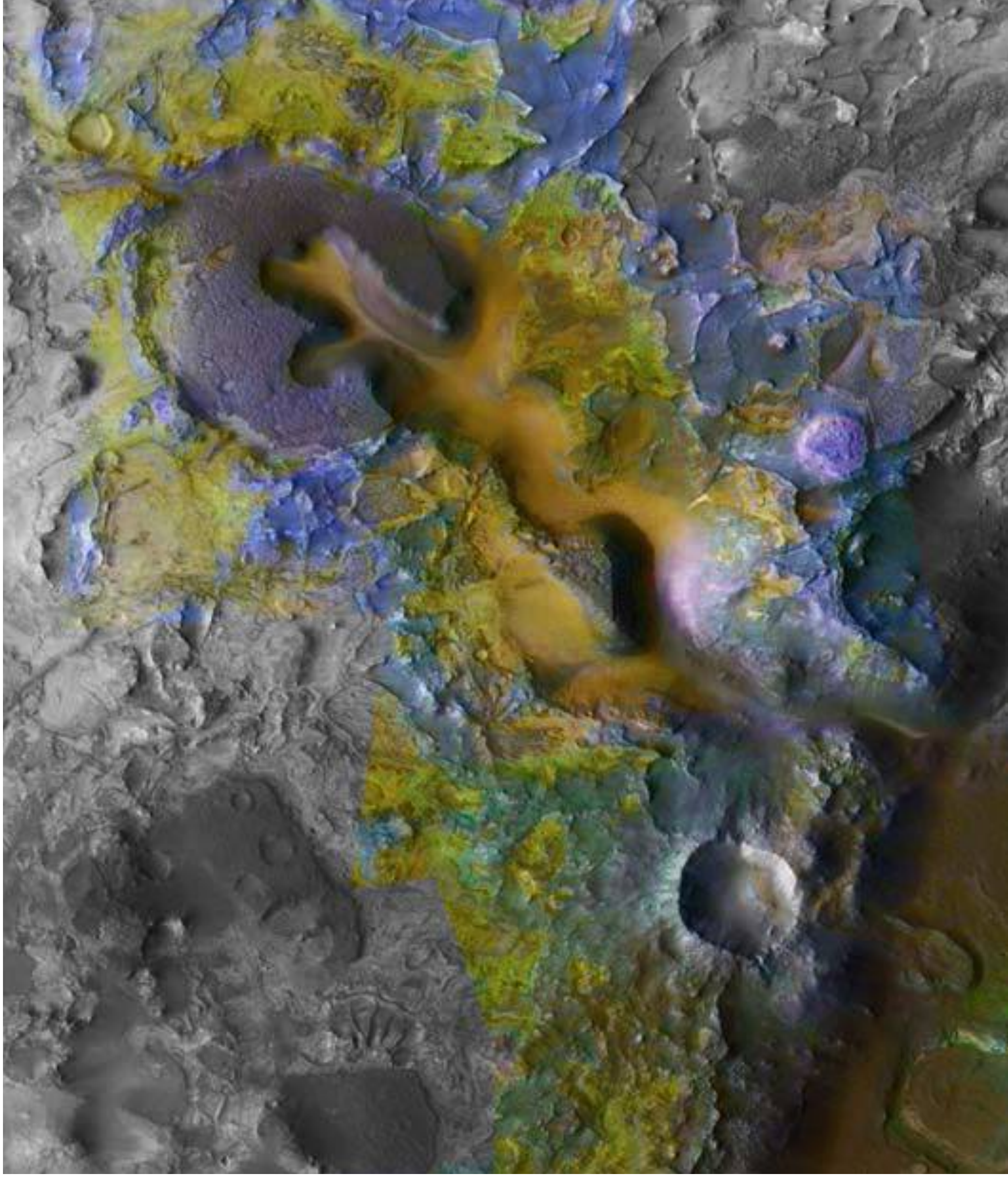
NASA/JPL/University of Arizona

Stair-step layers in Becquerel Crater consist of a series of bundles that contain 10 individual layers each. Scientists think the pattern corresponds to a known 10-to-1 ratio in how the tilt of Mars' rotation axis changes. In this region, the individual layers average about 12 feet (3.6m) thick.

Richard Talcott *is a senior editor of* Astronomy.



The Nili Fossae region of faults holds the best-exposed rocks containing carbonates. Clay-rich soil dominates this tiny section of Nili Fossae. NASA/JPL/University of Arizona



Carbonate minerals show up as small patches of green in this image that combines data from MRO's Context Camera and CRISM instrument. (Olivine-bearing rocks [yellow] occupy the same level as the carbonates, below the top [purple] layer.) The carbonates formed in a wet and non-acidic environment, one perhaps conducive to the formation of life. NASA/JPL/JHUAPL/MSSS/Brown University

area from slightly different angles in orbit, scientists determined each layer's thickness. "It's easy to be fooled without knowing the topography, and measuring the layers, in three dimensions," says University of Arizona planetary scientist Alfred McEwen, the camera's principal investigator. "With the stereo information, it is clear there's a repeating pattern to these layers."

The layers eroded at different rates. Apparently, some periodic change in the environment affected the resistance of the rock-forming sediments. "Each layer has weathered into a stair-step in the topography where material that's more resistant to erosion lies on top of material that's less resistant," says Kevin Lewis, the Caltech scientist who led the research team. The changes may reflect differences in the size of the particles deposited by the wind or in how local conditions cemented the particles.

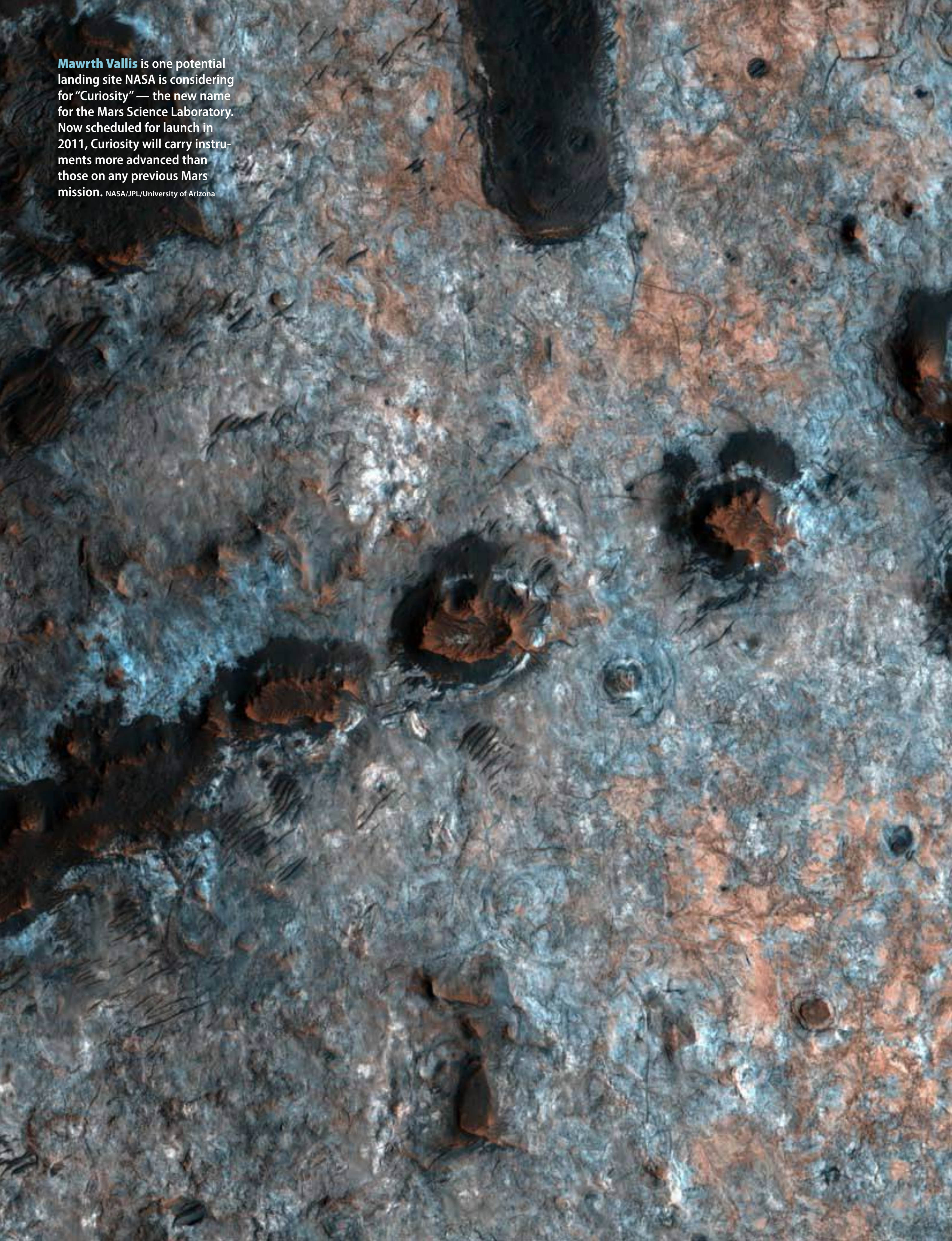
Mars' axis currently tilts 25.2° to the plane of its orbit. But this value varies by tens of degrees during an approximately 120,000-year cycle. (For comparison, Earth's large Moon stabilizes our planet's tilt, so it varies only between 22.1° and 24.5° during a 41,000-year period.)

Lewis and his colleagues think each layer formed in a 120,000-year period. This is where it gets interesting. "Mars has a 10-to-1 ratio in cycles of how its tilt changes — smaller wobbles within larger packages," says Lewis. "Sure enough, we see a 10-to-1 ratio in Becquerel's layered deposits." If true, the 10-layer bundles represent an approximately 1.2-million-year climate cycle. And the 10 or more stacked bundles seen in Becquerel Crater would record roughly 12 million years of Mars' climate.

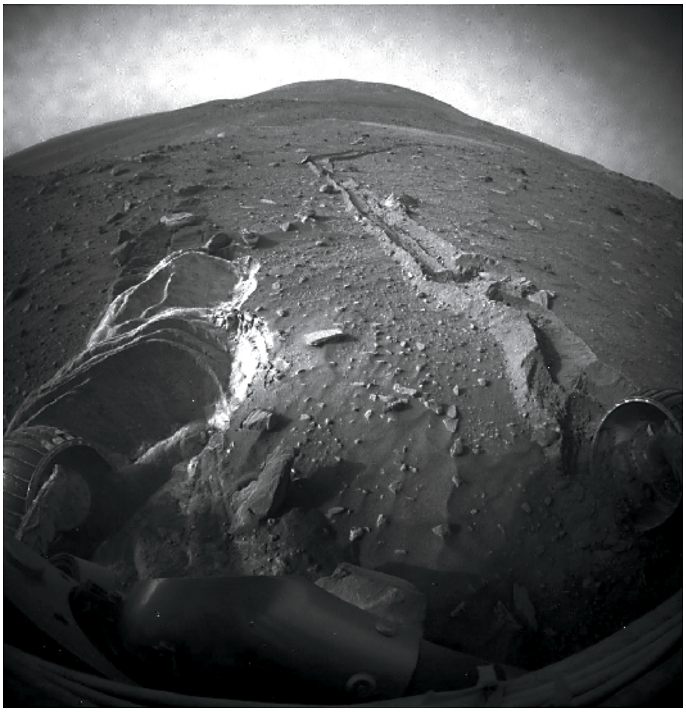
An acid test for water

While some scientists use Mars' rocky surface to understand past climate, others study it to learn about the planet's composition. Yet when researchers recently found long-sought carbonate minerals, they learned not only about composition but also about liquid water and the possibility of martian life.

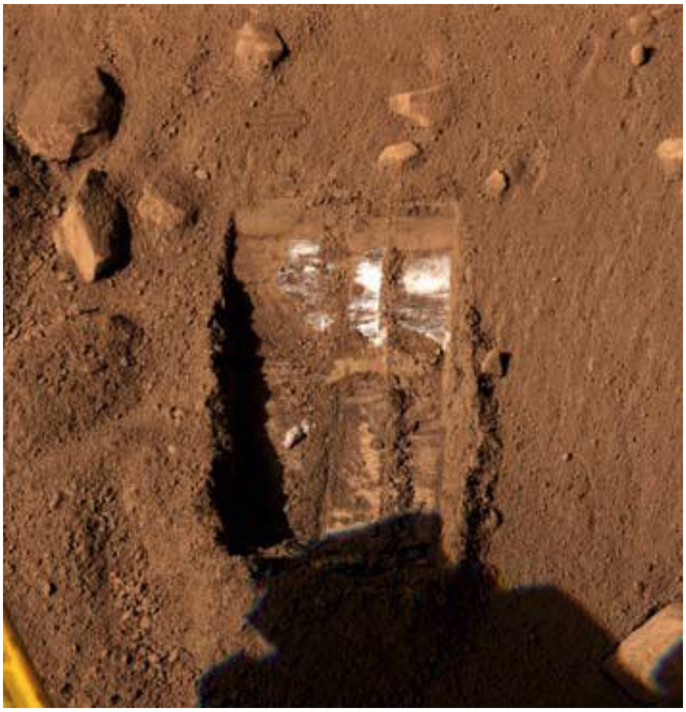
The carbonates turned up in observations made with MRO's Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). Bethany Ehlmann



Mawrth Vallis is one potential landing site NASA is considering for "Curiosity" — the new name for the Mars Science Laboratory. Now scheduled for launch in 2011, Curiosity will carry instruments more advanced than those on any previous Mars mission. NASA/JPL/University of Arizona



The Spirit rover slipped in soft ground in April and by May became mired with its wheels about halfway buried. The rover's right front wheel (visible on the far right side of this photo) no longer rotates after being damaged earlier in the mission. NASA/JPL



NASA/JPL/University of Arizona/Texas A&M University

The white stuff in the Dodo-Goldilocks trench at the Phoenix landing site turned out to be water ice. Even more importantly, the material Phoenix dug out from this trench proved rich in perchlorate salts, a finding that has scientists reassessing how they think about life on Mars.

of Brown University led a research team that discovered the deposits in bedrock layers surrounding the Isidis Basin, an impact structure 925 miles (1,489 kilometers) wide that formed more than 3.6 billion years ago. The best-exposed rocks occur along Nili Fossae, a system of troughs that extends some 415 miles (667 km).

Carbonate rocks, which on Earth include limestone and chalk, form when water and carbon dioxide interact with calcium, iron, or magnesium. Because carbonates dissolve quickly in acid, their survival challenges the idea that all of Mars experienced an intense bout of acidic weathering some 3.5 billion years ago. And if the planet once had a range of wet environments, says Ehlmann, it increases the chance that life might have started in one of them.

The Phoenix Mars Lander also found martian water from its perch in the north polar region. The 2008 mission gathered ice-rich samples that, when analyzed onboard, proved to contain frozen water. This wasn't a surprise. But a set of small globules found on struts of one of the lander's legs set off a frenzy.

Some scientists think the globules were droplets of liquid water. Others aren't convinced. Phoenix team member Nilton Renno of the University of Michigan proposes that perchlorate salts discovered at the site could raise ice's melting point enough to create water. Lab experiments performed by University of Arkansas researcher Vincent Chevrier and his graduate students show a solution of water and perchlorates could exist as a liquid in the martian arctic for a few hours on summer days.

The perchlorate salts also raised some eyebrows. None of the Phoenix team expected to find perchlorate, an ion that consists of one chlorine atom surrounded by four oxygen atoms. It occurs naturally on Earth in dry environments, like Chile's Atacama Desert. Early Internet speculation implied perchlorates made life either more likely or nearly impossible. But JPL's Michael Hecht, lead scientist for the team that detected the salts, says: "Finding perchlorates is neither good nor bad for life, but it does make us reassess how we think about life on Mars."

Into the future

Phoenix last communicated with Earth in November. Its solar panels simply could not generate energy as the Sun sank low in the northern hemisphere's sky. Still, it lasted 2 months longer than originally designed.

Spirit and Opportunity continue to explore the martian surface. No one knows how much longer they can survive. Although the plucky spacecraft have exceeded all expectations, their best days are behind them. In May, Spirit became stuck in soft soil near a low plateau known as "Home Plate." Opportunity was faring better, as it made its way toward Endeavor Crater.

Of the three orbiting spacecraft, both Mars Odyssey and Mars Express are on their third mission extensions. MRO continues to be the workhorse, returning more data than any previous mission to a planet and still within its first extension.

These five will remain the only Mars spacecraft for another 2 years. NASA recently announced that the Mars Science Laboratory, renamed "Curiosity" in May, won't launch until late 2011. NASA has yet to decide where to land this rover, but it has narrowed the choices considerably in the past year. Curiosity will assess whether Mars ever had an environment able to support microbial life and whether it still does today. Until then, the current crop of missions will continue to reveal the Red Planet.

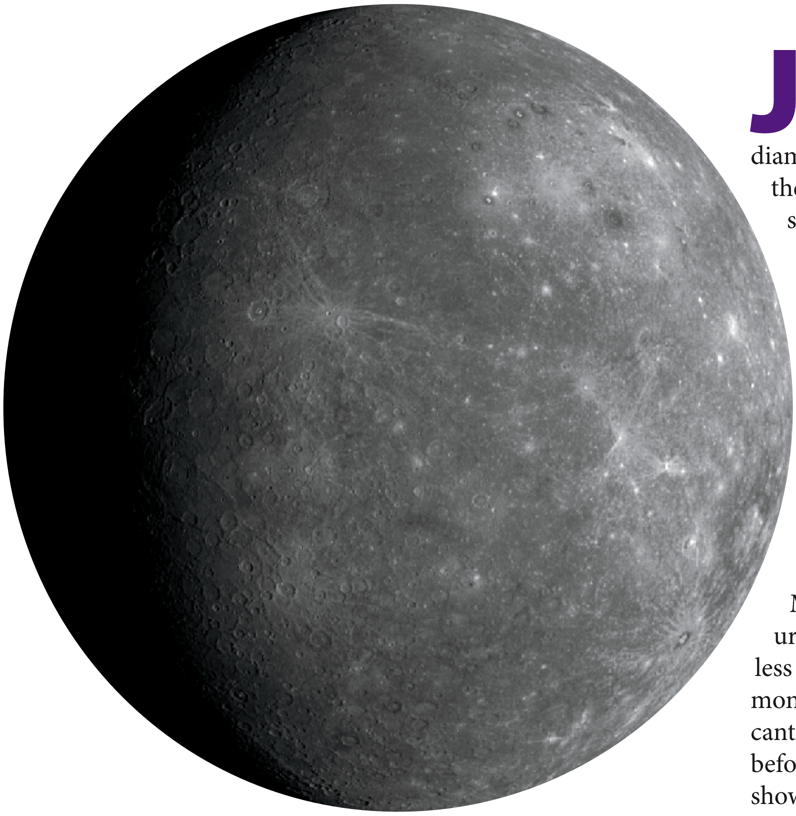
Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

October 09

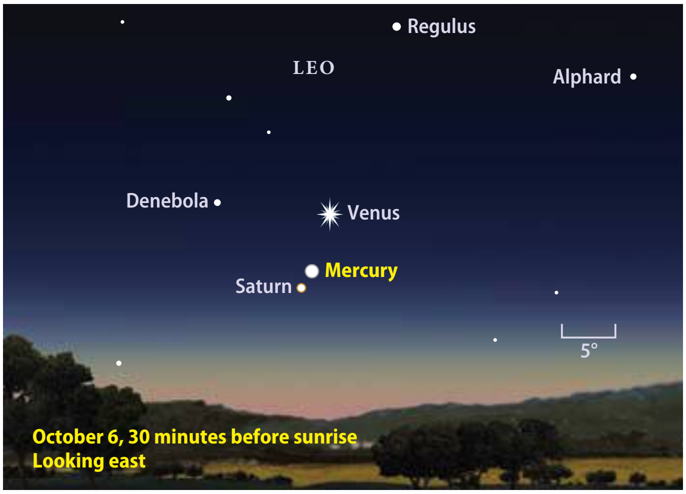
Mercury's morning show

40	**Mercury at its best**	👁 ⚯ 🔭
45	**Meteor watch**	👁
45	**Rising Moon**	🔭
46	**When to view the planets**	👁 ⚯ 🔭
46	**Io occults Europa**	🔭
46	**Comet search**	🔭
47	**Locating asteroids**	⚯ 🔭
47	**Mars joins the Beehive**	⚯ 🔭

👁 **Visible to the naked eye**
⚯ **Visible with binoculars**
🔭 **Visible with a telescope**



Mercury looms large in this MESSENGER spacecraft image. Expect to see more stunning close-ups this month as the probe returns data from its September 29 flyby. NASA/JHUAPL/CIW



October 6, 30 minutes before sunrise
Looking east

Mercury appears bright before dawn at greatest elongation October 5/6. Look for it one binocular field below dazzling Venus. *Astronomy*: Roen Kelly

Jupiter is the first planet to come into view these autumn evenings. Its diamondlike sparkle pierces the twilight sky shortly after sunset. The giant planet's neighbors Uranus and Neptune both present excellent targets for observers with binoculars and telescopes throughout October.

The four remaining planets lie in the morning sky. Three of them appear near one another and low in the twilight: Mercury, Venus, and Saturn. Both inner planets pass less than 1° from Saturn this month. Mars climbs significantly higher than the others before dawn and starts to show detail to those who turn a telescope toward it.

Let's start where we normally do, with the bright planets of the evening sky. **Jupiter**, the king of the solar system, stands nearly due south after twilight fades away. You'll find it among the background stars of Capricornus the Sea Goat. Truth be told, the brilliant planet makes a better guide to the dim constellation than vice versa. In mid-October, Jupiter gleams at magnitude –2.6.

Jupiter's distance from Earth increases nearly 10 percent during October, ending the month 442 million miles away. This results in a nearly 10 percent drop in Jupiter's apparent size, from 45.5" October 1 to 41.5" October 31. Still, the planet appears more than twice the size of any other. That's the main reason the jovian atmosphere exhibits so much fine detail when viewed through even small telescopes.

To see the most features, observe Jupiter shortly after darkness falls. The planet then stands fairly high in the sky, so we observe it through less of Earth's atmosphere. Super-steady views may be hard to come by, however, because our atmosphere tends to cool off rapidly after sunset as it loses its daytime heat. The resulting turbulence degrades telescopic images. If the air is unsteady, keep the magnification low for better views.

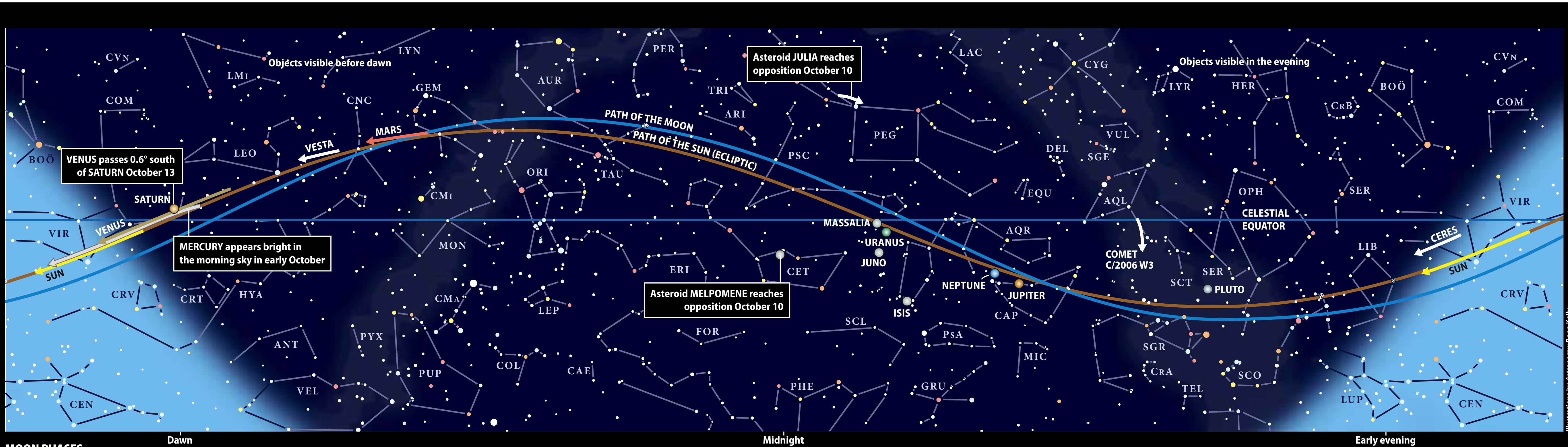
— Continued on page 45

Planets in October 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets


Objects visible before dawn
Objects visible in the evening
VENUS passes 0.6° south of SATURN October 13
MERCURY appears bright in the morning sky in early October
Asteroid JULIA reaches opposition October 10
Asteroid MELPOMENE reaches opposition October 10
COMET C/2006 W3
PATH OF THE MOON
PATH OF THE SUN (ECLIPTIC)
CELESTIAL EQUATOR
SUN
VENUS
SATURN
VESTA
MARS
MASSALIA
URANUS
JUNO
NEPTUNE
JUPITER
ISIS
PLUTO
CERES
SUN
CVN
LMI
LYN
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Dawn
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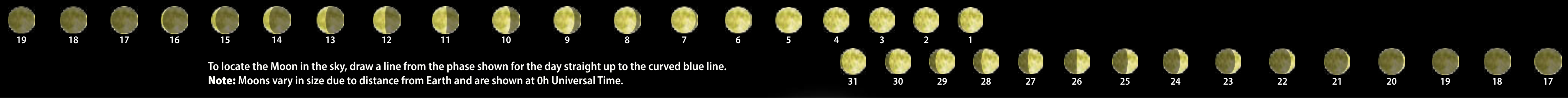
Early evening

Illustrations by Astronomy: Roen Kelly

MOON PHASES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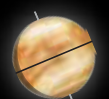
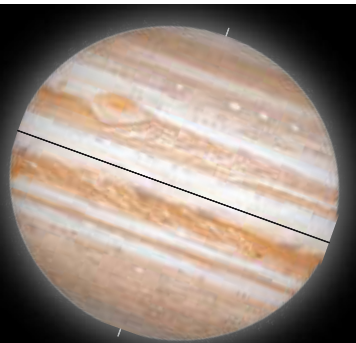
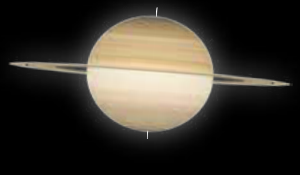
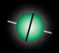
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.



PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	October 1	October 15	October 15	October 15	October 15	October 15	October 15	October 15	October 15
Magnitude	0.4	– 3.9	0.7	8.6	– 2.6	1.1	5.7	7.9	14.0
Angular size	8.2"	10.8"	7.1"	0.4"	43.7"	16.0"	3.7"	2.3"	0.1"
Illumination	28%	93%	88%	100%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.823	1.543	1.313	3.619	4.514	10.358	19.213	29.486	32.062
Distance (AU) from Sun	0.311	0.719	1.543	2.646	5.023	9.452	20.098	30.027	31.723
Right ascension (2000.0)	11h29.8m	12h02.1m	8h05.6m	14h02.7m	21h19.3m	11h56.6m	23h37.2m	21h44.5m	18h03.4m
Declination (2000.0)	3°36'	1°25'	21°24'	– 6°31'	–16°44'	2°34'	– 3°20'	–14°02'	–18°06'

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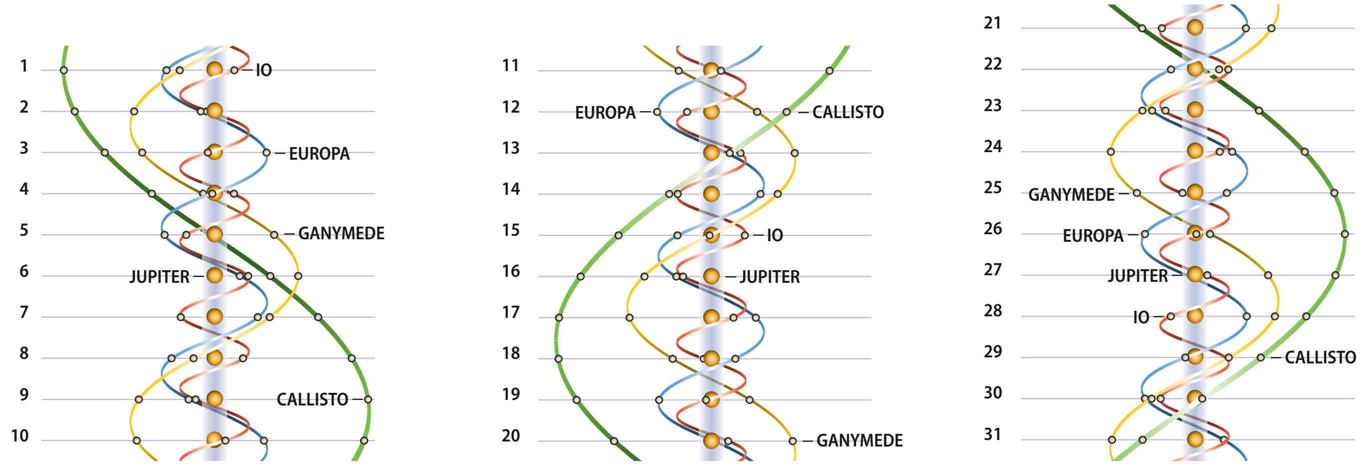
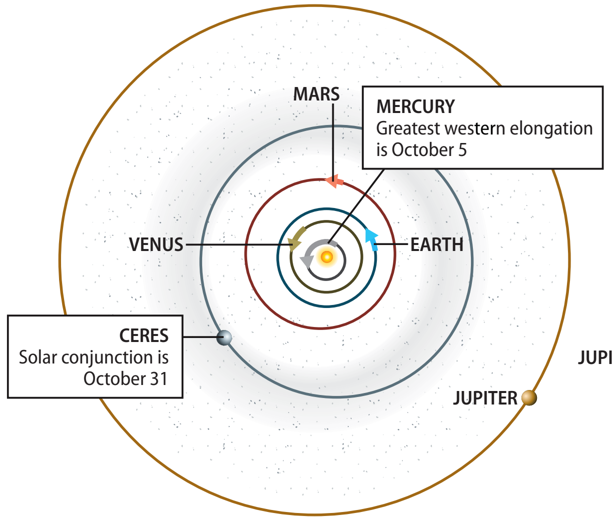
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.



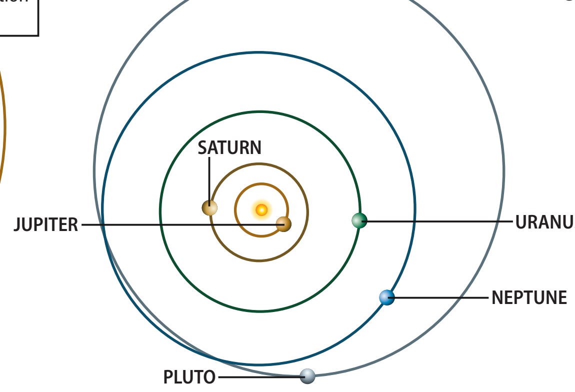
The planets in their orbits

Arrows and dots show
planets' positions
during October.


MARS
VENUS
EARTH
JUPITER

MERCURY
Greatest western elongation is October 5

CERES
Solar conjunction is October 31


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

StarDome

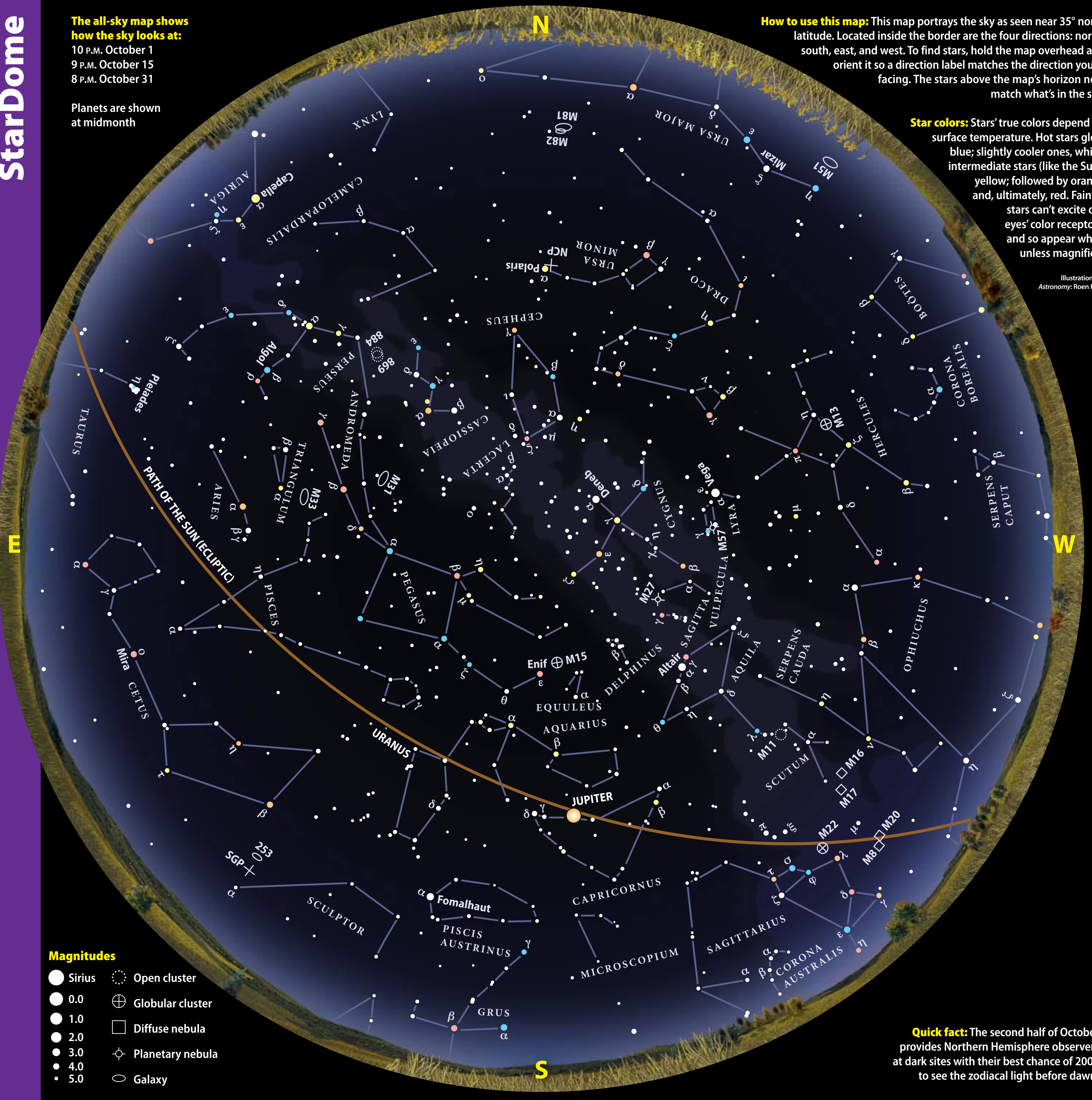
The all-sky map shows how the sky looks at:
10 P.M. October 1
9 P.M. October 15
8 P.M. October 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly


N
E
W
S
LYNX
M81
M82
URSA MAJOR
Mizar
M51
AURIGA
Capella
CAMELOPARDALIS
NCP
Polaris
URSA MINOR
DRACO
BOÖTES
CEPHEUS
Algol
PERSEUS
884
869
Pleiades
TAURUS
CASSIOPEIA
LACERTA
ANDROMEDA
M31
TRIANGULUM
M33
ARIES
Deneb
CYGNUS
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
SERPENS CAPUT
PATH OF THE SUN (ECLIPTIC)
PISCES
PEGASUS
M27
VULPECULA
SAGITTA
Mira
CETUS
Enif
M15
EQUULEUS
DELPHINUS
Altair
AQUILA
SERPENS CAUDA
OPHIUCHUS
AQUARIUS
URANUS
M11
SCUTUM
M16
M17
JUPITER
M22
M8
M20
253
SGP
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
CAPRICORNUS
MICROSCOPIUM
SAGITTARIUS
CORONA AUSTRALIS
GRUS

Magnitudes

● Sirius	⁛ Open cluster
● 0.0	⊕ Globular cluster
● 1.0	☐ Diffuse nebula
● 2.0	✧ Planetary nebula
● 3.0	⬭ Galaxy
• 4.0	
• 5.0	

Quick fact: The second half of October provides Northern Hemisphere observers at dark sites with their best chance of 2009 to see the zodiacal light before dawn.

October 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Calendar of events

2 The Moon passes 6° north of Uranus, 10 P.M. EDT

4 Full Moon occurs at 2:10 A.M. EDT

5 Mars passes 6° south of Pollux, 6 P.M. EDT

Mercury is at greatest western elongation (18°), 10 P.M. EDT

Special observing date

5 The peak of Mercury's best morning apparition of 2009 comes at today's greatest elongation.

8 Mercury passes 0.3° south of Saturn, 5 A.M. EDT

10 Asteroid Julia is at opposition, 5 P.M. EDT

Asteroid Melpomene is at opposition, 6 P.M. EDT

11 Last Quarter Moon occurs at 4:56 A.M. EDT

The Moon passes 1.2° south of Mars, 9 P.M. EDT

13 Jupiter is stationary, 5 A.M. EDT

The Moon is at perigee (229,327 miles from Earth), 8:24 A.M. EDT

13 Venus passes 0.6° south of Saturn, noon EDT

16 The Moon passes 7° south of Saturn, 9 A.M. EDT

The Moon passes 7° south of Venus, 3 P.M. EDT

18 New Moon occurs at 1:33 A.M. EDT

21 Orionid meteor shower peaks

The Moon passes 1.0° north of Antares, 11 A.M. EDT

25 The Moon is at apogee (251,137 miles from Earth), 7:18 P.M. EDT

First Quarter Moon occurs at 8:42 P.M. EDT

27 The Moon passes 3° north of Jupiter, 5 A.M. EDT

The Moon passes 3° north of Neptune, 5 P.M. EDT

30 The Moon passes 6° north of Uranus, 5 A.M. EDT

31 Asteroid Juno is stationary, 6 A.M. EDT

Asteroid Ceres is in conjunction with the Sun, 11 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 40*

The most obvious features in Jupiter's cloud tops are the two dark equatorial belts that sandwich a brighter equatorial zone. Finer structures appear on the belts' northern and southern boundaries, which are transition regions between areas of different wind speeds. The high relative winds generate intriguing cloud features that frequently change shape. These features appear subtle to the eye, so you'll want to watch patiently and wait for moments of good seeing.

Jupiter's appearance changes in as little as a half-hour. For example, the planet's rapid spin (it completes a rotation in less than 10 hours) carries features that lie near the center of the disk more than halfway to the limb in less than an hour. The speedy rotation also causes Jupiter's noticeable flattening. The planet's polar diameter measures 6 percent less than its equatorial diameter.

Jupiter observers will notice one other aspect in constant flux: the positions of the planet's four brightest moons. Io, Europa, Ganymede, and Callisto provide a fascinating sideshow to the activity in Jupiter's cloud tops. Because we view their circular orbits nearly edge-on, the moons appear to dance back and forth with Jupiter as their central anchor.

On a few of these dances, one moon passes in front of another and occults it from view. North American observers can watch two such events in late October. On the 23rd, starting at 8:31 P.M. EDT and lasting for 9 minutes, Ganymede occults Europa. One night later, Io occults Europa beginning at 9:18 P.M. EDT and ending 7 minutes later.

Capricornus holds a second giant planet, but you'll have to hunt for dim **Neptune**. The solar system's outermost planet lurks in the constellation's northeastern

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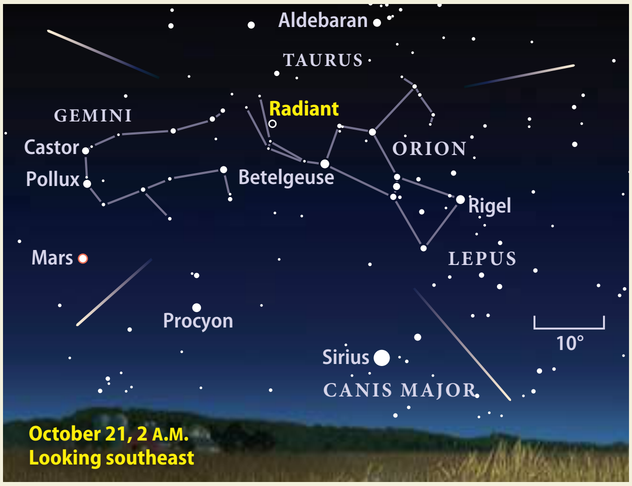
Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Orionid meteor shower peaks before dawn October 21. With no Moon to interfere, observers with dark skies can expect to see up to 30 meteors per hour. *Astronomy*: Roen Kelly

Halley's debris ignites celestial show

Autumn meteor viewing gets rolling with the Orionid shower. Astronomers predict the Orionids will generate up to 30 meteors per hour at their peak before dawn October 21. This so-called zenithal hourly rate measures the number of meteors observers could expect to see under a dark sky if the radiant were overhead.

Activity could come close to this level. The shower's radiant lies in northeastern Orion, so it climbs high before dawn's first light. And this year, the Moon is only 3 days old and sets well before the prime observing hours after midnight.

The Orionids derive from tiny dust particles ejected by Comet 1P/Halley during its innumerable orbits of the Sun. These bits of flotsam hit our atmosphere at 41 miles per second, a speed second only to November's Leonid meteors.

Rising **Moon**

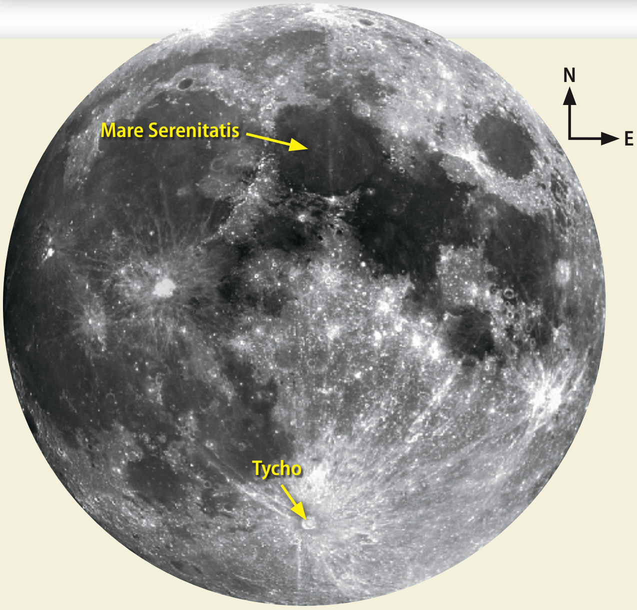
Sunlight splashes on the Sea of Serenity

Long, thin rays of bright material adorn the dark patches of lunar lava around Full Moon. This month, Full Moon arrives the night of October 3/4, although the rays appear conspicuous the nights before and after that. The bright streaks arise from debris splashed out by large and relatively recent impacts.

To view rays and other features of a Full Moon through a telescope, you need to keep from being dazzled. An inexpensive neutral density filter will help open Luna's face.

Striking ray systems surround the large craters Copernicus and Kepler, both of which lie in the Moon's western hemisphere just north of the equator. But the most impressive rays belong to Tycho, an otherwise unexceptional crater deep in the lunar south. Tycho's longest ray cuts through the middle of the nearly circular Mare Serenitatis (the Sea of Serenity).

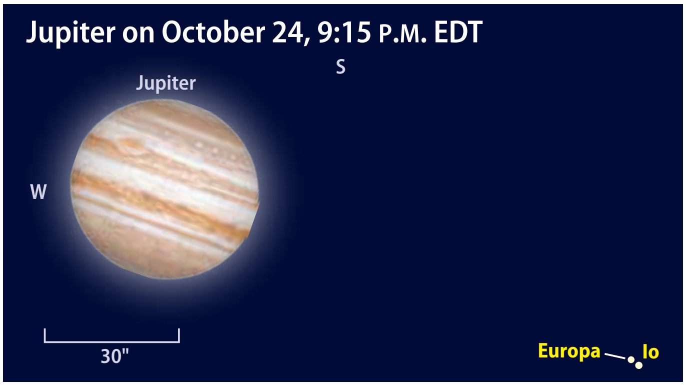
Tycho's rays appear bright for two reasons. First, the impact that formed the crater unearthed lighter-hued highland material from below. And second, Tycho is youthful as far as lunar craters go — a mere 108 million years old. The fresh material the crater-impact dredged up and scattered about has not had time to darken under the solar wind's sandblasting effect.



The Full Moon's splashiest rays emanate from the otherwise inconspicuous crater Tycho. One of these white streaks reaches all the way to Mare Serenitatis (the Sea of Serenity). Adam Stuart

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Jupiter (southeast)	Jupiter (southwest)	Mercury (east)
Uranus (southeast)	Uranus (south)	Venus (east)
		Mars (southeast)
		Saturn (east)


Jupiter on October 24, 9:15 P.M. EDT

Jupiter's moons Io and Europa appear to merge the evening of October 24. This view shows the pair slightly before Io starts to occult Europa at 9:18 P.M. EDT. The event lasts just 7 minutes. *Astronomy*: Roen Kelly

corner. Look for it about 2° north of the 3rd-magnitude star Delta (δ) Capricorni. Neptune lies just east of a line of three stars, the brightest of which is 5th-magnitude 42 Capricorni.

Neptune glows at magnitude 7.9. Through binoculars or a telescope at low magnification, it appears just like a faint star. At magnifications of 150x or more, you'll see the planet's 2.3"-diameter disk and subtle blue-gray hue.

The final evening planet, **Uranus**, lies about 30° east-northeast of Neptune. It glows at magnitude 5.7, which makes it an easy target through binoculars. You might even glimpse it with your naked eyes under a dark sky. Uranus continues to move westward against the background stars in October, crossing from Pisces into Aquarius around midmonth.

To find Uranus, first locate the Great Square of Pegasus. It lies due south and more than two-thirds of the way to the zenith around 11 P.M. local daylight time. Then shift your gaze below the Square and pick up the Circlet asterism of Pisces. Uranus lies 5° south of the Circlet's southeastern star, Lambda (λ) Piscium. Through a telescope, Uranus appears distinctly blue-green and spans 3.7".

Not long after midnight, you should see the ruddy glow of **Mars** climbing in the eastern sky. It begins October south of the bright stars Castor and Pollux, the luminaries of Gemini the Twins. At magnitude 0.8, Mars appears noticeably brighter than the twin stars.

The Red Planet crosses into Cancer the Crab in mid-October and approaches the Beehive star cluster (M44) by month's end. It stands just 1 Moon-width from the cluster's center before dawn October 31. This chance alignment will provide fine views through binoculars or a low-power telescope. That morning, Mars shines at magnitude 0.5.

Planet observers have been patient all year, waiting for Mars to grow large enough to show some detail through a telescope. The wait is finally coming to an end. In late October, the Red Planet's disk appears 8" across — big enough to reveal features in 8-inch and larger scopes. The most obvious is the white north polar cap. It's on display now because Mars' northern hemisphere tilts toward Earth.

The polar cap will shrink during the next few months as the temperature warms in this region. (Spring begins in the northern hemisphere October 26.) And observing Mars will only get easier. The planet's

Comet search

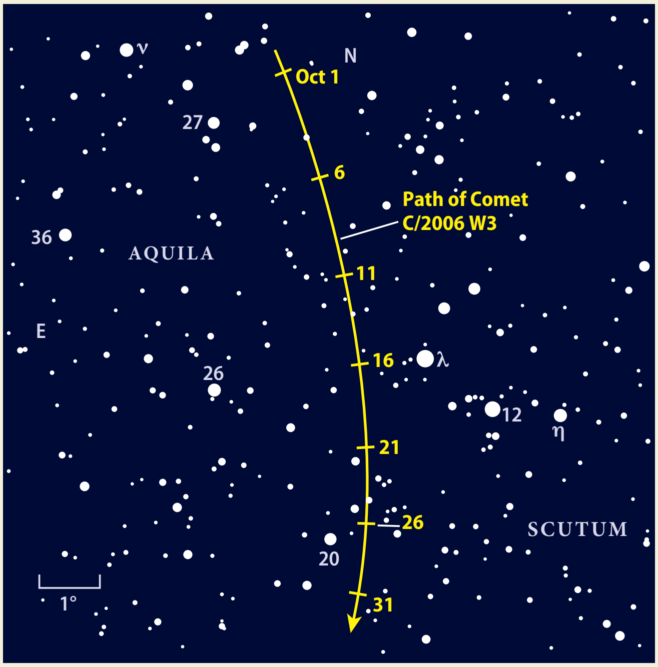
Comets glow at both dusk and dawn

If our luck holds out, October should bring a reasonably bright evening comet. Astronomers initially thought Comet C/2006 W3 (Christensen) would peak around 12th magnitude. This past spring, however, it climbed to 9th magnitude. If the trend continues, it could glow around 8th magnitude in October.

The best views will come during October's second and third weeks, when the Moon is out of the evening sky. Use the finder chart to track Christensen as it slides south through the rich Milky Way star fields of Aquila the Eagle. It passes 1° east of the 3rd-magnitude star Lambda (λ) Aquilae at midmonth.

Keen comet-chasers should try to spot C/2007 Q3 (Siding Spring) before dawn as the month begins. The draw of early October: The comet floats a few degrees from brilliant Venus. The rest of us should wait until the next dark-of-the-Moon window opens around the 17th.

The comet passes just 15' north of the 11th-magnitude galaxy NGC 3705 in Leo October 22. The conjunction of this visitor from the outer solar system with the far more distant galaxy creates a nice photo opportunity for astroimagers.



Comet C/2006 W3 (Christensen) should reach 8th magnitude this month among the background stars of Aquila the Eagle. *Astronomy*: Roen Kelly

Locating **asteroids**

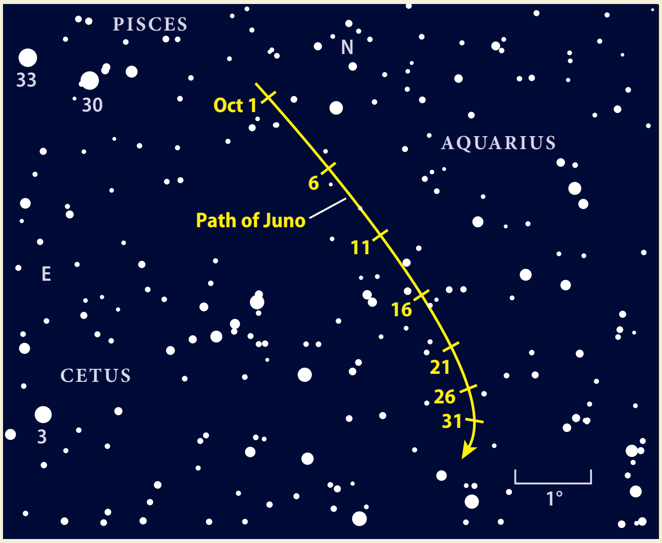
Juno splashes in autumn's watery realm

Asteroid 3 Juno emerges as October's best target among the "Big Four" asteroids. This unlikely candidate — it normally glows dimmer than the other three — shines at 8th magnitude and rides high in the late-evening sky. It dives south this month through the eastern part of Aquarius the Water-bearer, near this constellation's border with Pisces the Fish and Cetus the Whale.

Backyard observers with go-to telescopes can find Juno in a snap. It will take a few minutes to reach this field if you use the traditional star-hopping method. Still, you should count yourself lucky. When German astronomer Karl Harding discovered Juno in September 1804, he had to compare every eyepiece field to a star chart, looking to see if any point of light did not belong.

In mid-October, you can find Juno quite easily. Aim your telescope at the 4th-magnitude stars Psi^1 (ψ^1) and Psi^2 (ψ^2) Aquarii. Then, turn off the drive (if you have one), return in 28 minutes, and nudge the scope 0.5° north. On the 15th, Juno will be right there. For any other date, follow the path plotted at right to the correct field.

Harding had luck on his side when he discovered Juno. The asteroid was then making a close approach to Earth, similar to this autumn, and shone at 8th magnitude.



Juno glows at 8th magnitude as it treks south through far eastern Aquarius. This normally dim asteroid outshines all others during the first half of October. *Astronomy*: Roen Kelly

disk will grow 2" during November and another 3" in December. Mars will reach opposition and peak visibility in January 2010.

Three planets appear close to one another in early October's predawn sky. **Venus** rises first, coming up 2 hours before the Sun October 1. At magnitude –3.9, the planet is dazzling. The view through a telescope proves less impressive. Venus shows a bland disk 11" across and 90 percent lit.

Mercury rises 45 minutes after Venus on the 1st. At magnitude 0.4, the innermost planet shines just 2 percent as bright as Venus. But Mercury brightens each day throughout the month. When the planet reaches greatest western elongation October 5/6, it gleams at magnitude –0.6.

Early October marks the high point of Mercury's best morning apparition of 2009 for Northern Hemisphere observers. At greatest elongation, it appears 11° high in the east 30 minutes before sunrise. The view through a telescope changes daily. On the 1st, the planet appears 8" across and barely one-quarter lit. By the 6th, its diameter dips to 7" while its phase waxes to half-lit.

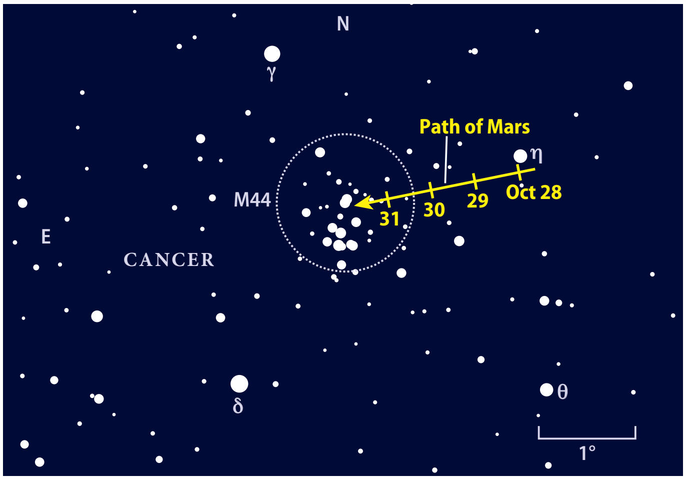
The final predawn planet presents a greater challenge, at least as October begins. **Saturn** rises in the brightening twilight some 20 minutes after Mercury. And Saturn appears dimmer, too, at magnitude 1.1. The two planets edge closer each morning. On October 8, they pass just 0.3° from each other. With Mercury shining at magnitude –0.8, it serves as a guide for spotting Saturn.

That same morning, Venus lies 5° above the pair. With each passing day, Mercury descends into brighter twilight while Saturn climbs higher. The ringed planet soon closes the gap with Venus. The two meet October 13, when a single Moon-width separates the pair. Mercury lies 6° below.

Three mornings later, on the 16th, a waning crescent Moon lies well to the right of the planet trio. Mercury then shines at magnitude –1.0 and still rises an hour before the Sun. But Mercury's days are numbered, and it drops out of view by month's end. Because Venus orbits the Sun more slowly than Mercury, it takes longer to succumb to the Sun's glow. Venus will stay in sight through November.

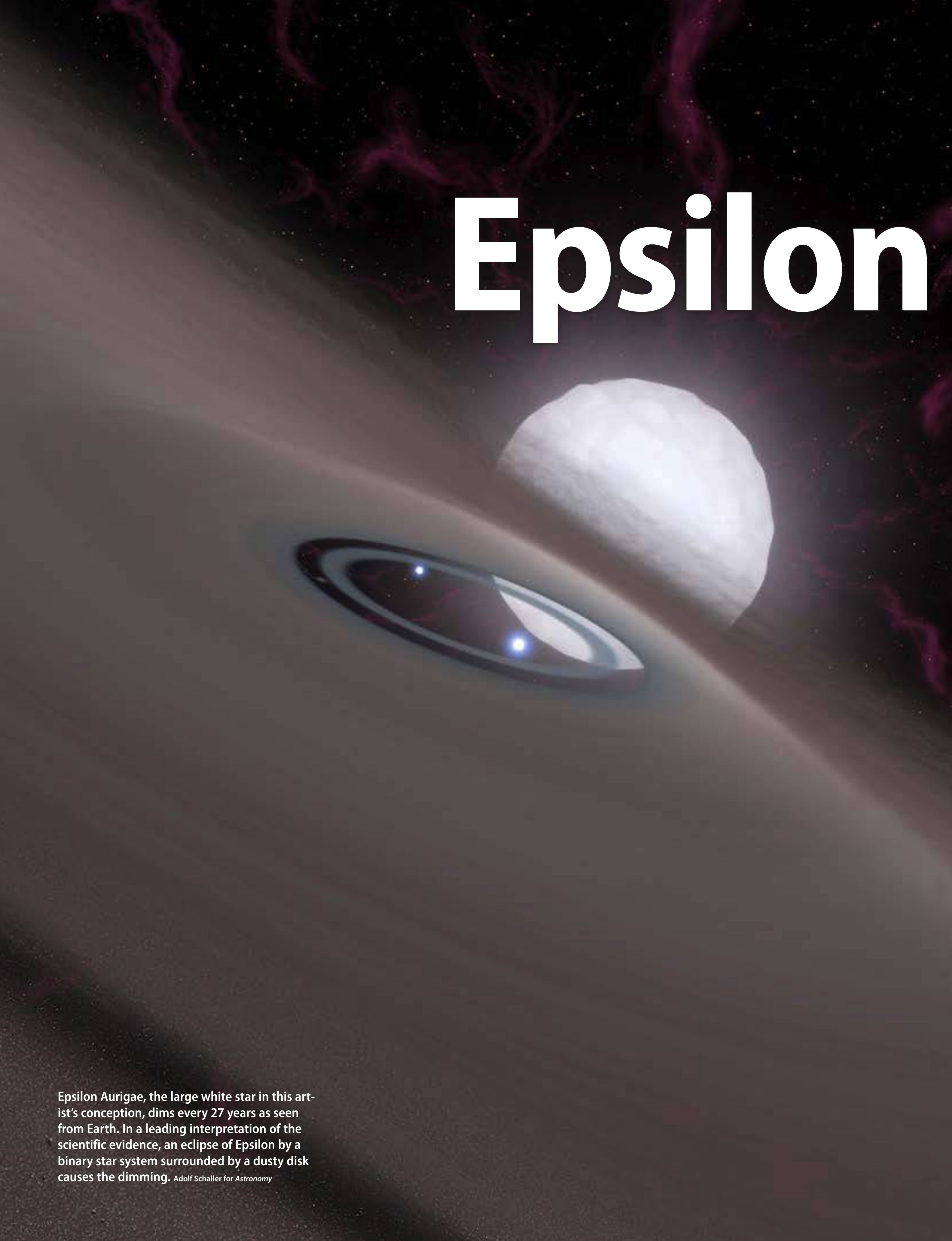
Saturn fares much better. It rises 3 hours before the Sun October 31 and climbs some 20° high by the time twilight begins. After spending most of the year among the stars of southern Leo, the ringed planet now lies in the direction of western Virgo.

Saturn provides a dramatic view through a telescope. Although the rings were edge-on to Earth just last month, their tilt increases rapidly. They tip 3° to our line of sight by late October and span 37". By the end of 2009, the tilt will have increased to 5°. This is our first view of the rings' northern face in 14 years.



Mars joins the Beehive star cluster (M44) at the end of October. On the 31st, Mars appears within the cluster's border, and the pair looks spectacular through binoculars or a low-power telescope. *Astronomy*: Roen Kelly

Epsilon



Epsilon Aurigae, the large white star in this artist's conception, dims every 27 years as seen from Earth. In a leading interpretation of the scientific evidence, an eclipse of Epsilon by a binary star system surrounded by a dusty disk causes the dimming. Adolf Schaller for *Astronomy*

Aurigae: Astronomy’s longest-running mystery show

A huge, unknown object is dimming this supergiant star’s light, just as it did 27 years ago. New technology may soon tell us what it is. **by Robert Zimmerman**

A celestial sleight-of-hand is underway. The bright star Epsilon (ε) Aurigae began to dim this summer. Bit by bit, it will darken by almost a full magnitude on the astronomical brightness scale, becoming 2.5 times dimmer. Then it will languish at this shadowed state for the next year or more before slowly returning to its normal brilliance in the constellation Auriga the Charioteer.

Astronomers strongly suspect the dimming is some sort of eclipse event, in which an orbiting companion periodically passes in front of Epsilon Aurigae and blocks a portion of its light. Since 1821, astronomers have seen the star fade 7 times, every 27 years or so. And yet, as predictable as these eclipses have been, the underlying cause remains one of the oldest mysteries of modern astronomy.

The physical nature of the object that eclipses Epsilon Aurigae remains unknown. To produce such long eclipses, the obscuring object must be incredibly large — large enough that if it were placed at the center of our solar system, its surface would reach almost to the orbit of Uranus.

Further complicating matters, the eclipsing body does not appear to obscure Epsilon Aurigae entirely. Throughout the eclipse, a portion of Epsilon Aurigae’s light remains visible, as if the object obscuring it either doesn’t cover it entirely or covers it like the lenses in a pair of sunglasses — evenly blocking out a certain percentage of light at every wavelength but letting the rest through.

With each eclipse, a new generation of astronomers has attacked this mystery, coming at it each time with a new set of instruments. Yet, each time the new knowledge has only deepened the mystery. As astronomer Otto Struve wrote in 1962, “The history of the eclipsing binary Epsilon Aurigae is in many respects the history of astrophysics.”

> “The history of the eclipsing binary Epsilon Aurigae is in many respects the history of astrophysics.”
> **— OTTO STRUVE**

And now that history is about to get a new chapter. Modern telescope technology should provide the sharpest and most detailed views of the Epsilon Aurigae system ever. Combined with measurements of the star’s dimming cycle collected by dedicated amateur observers,

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Robert Zimmerman *is a frequent contributor to* Astronomy. *His most recent book is* The Universe in a Mirror: The Saga of the Hubble Space Telescope and the Visionaries Who Built It *(Princeton University Press, 2008).*

Capella
Epsilon (ε) Aurigae

Epsilon (ε) Aurigae is one of the brightest stars in the constellation Auriga the Charioteer. Bill and Sally Fletcher

the latest eclipse may finally unmask the secrets of one of astronomy's longest-running mystery shows.

The early observers

Epsilon Aurigae is a white supergiant star visible to the naked eye under moderately dark sky conditions. In 1821, German pastor and amateur astronomer Johann Fritsch noticed that Epsilon Aurigae had dimmed by a magnitude for about a year and then returned to its previous brightness. When the star dimmed again in 1848, and then again in 1876, astronomers realized they had something unusual on their hands.

The dimmings had occurred about 27 years apart. To modern astronomers, this would suggest a type of star system called an eclipsing binary, in which one of a pair of mutually orbiting suns periodically passes in front of the other, cutting off some or all of its light. To a distant observer, an eclipsing binary looks like a single star that shines steadily between periodic dips in brightness.

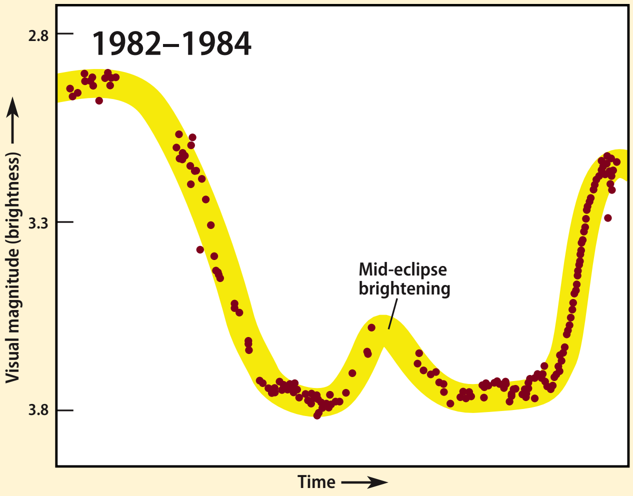
Nineteenth-century astronomers, however, labeled Epsilon Aurigae an "irregular variable" — a lone star changing in brightness. "Binary star theory just wasn't that developed in the 19th century," explains Robert Stencel of the University of Denver. Astronomers then were more familiar with variable stars and chose that phenomenon as their preferred explanation.

In 1903, the star dimmed a fourth time, precisely on schedule. Astronomers observed this one closely and found the star going through a slow 6-month decline in brightness, followed by a year-long flat minimum, and ending with a slow 6-month return to full brightness. It was then that astronomers finally realized for certain that this was not an irregular variable, but a strange and inexplicable eclipsing binary.

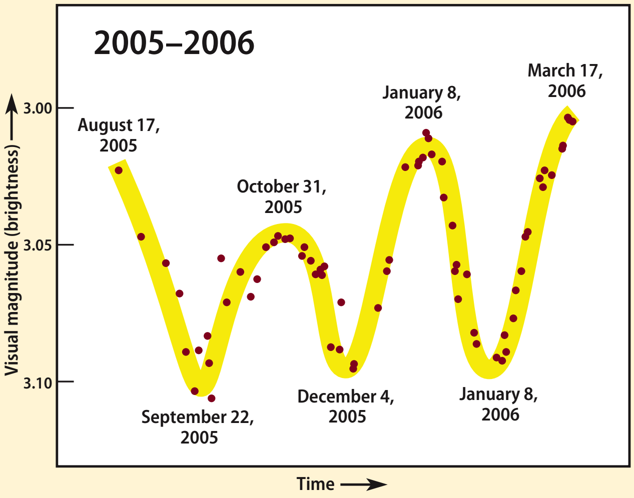
The length of the 1903 eclipse — the longest measured to date — left astronomers puzzled. Based on Epsilon Aurigae's estimated distance of about 2,000 light-years, only a truly immense object would be able to produce a 2-year-long eclipse. Scientists estimated its radius as 3,000 times that of the Sun, making it by far the largest stellar-type object they knew of at the time.

Light curves for Epsilon Aurigae

Light curves record changes in a star's brightness over time. These curves are based on data collected by advanced amateur astronomer Jeffrey L. Hopkins in Arizona. The brightnesses are given as visual magnitudes, or how bright the star seems to an observer on Earth. *Astronomy*: Roen Kelly, after Jeffrey L. Hopkins



The eclipse of 1982–1984 was the best-observed example of Epsilon Aurigae's periodic dimming and brightening cycle. In the middle of the period of maximum dimming, the star brightened briefly.



Between eclipses, Epsilon Aurigae's visual magnitude varies by a small amount, about 0.1 magnitude on the astronomical brightness scale.

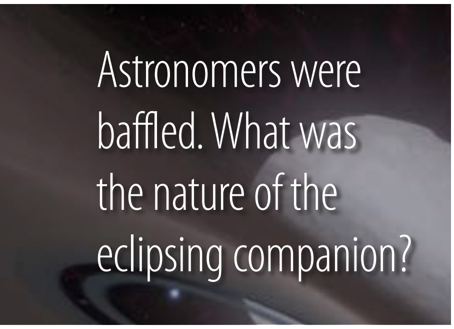
The 1903 eclipse was also the first observed with the aid of spectroscopy. Splitting Epsilon Aurigae's light into its component wavelengths (colors) revealed new mysteries about the unseen eclipsing body. During the entire eclipse, Epsilon Aurigae's spectrum of colors did not change. All the invisible companion did was dim the light of the visible star equally across all wavelengths, much as a pair of sunglasses diminishes the brightness of a sunny day.

In addition, the eclipsing companion produced no visible spectral signature of its own, so it was completely dark. The 1928–1930 and 1955–1957 eclipses only confirmed the observations and deepened the enigma.

Doughnuts in space

Astronomers were baffled. What was the nature of the eclipsing companion in the Epsilon Aurigae system? By the middle of the 20th century, they had arrived at a range of solutions, all of which were exotic but none very satisfying.

In 1924, German astronomer Hans Ludendorff proposed that a dense swarm of meteoroids orbiting the visible star causes the eclipses. Gerard Kuiper, Otto Struve, and Bengt Strömgren of the Yerkes Observatory topped Ludendorff in 1937. They speculated that the eclipsing companion is invisible because it emits its radiation entirely in the infrared. The radiation produces a gigantic solar-system-sized cloud of charged particles — an ionosphere — around the star. This ionosphere acts as a filter that blocks the visible companion star's light during the eclipse.



Astronomers were baffled. What was the nature of the eclipsing companion?

In 1955, Struve proposed that Epsilon Aurigae consists of an eclipsing binary encircled by a complex of gas clouds. The clouds are thick enough to block our view of the eclipsing star while also partly obscuring the light of the visible star.

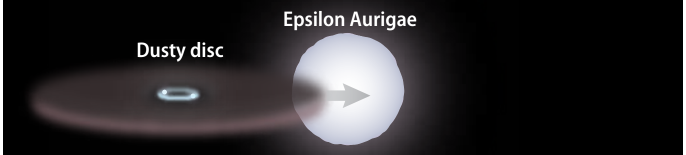
Data from the 1955–1957 and 1982–1984 eclipses helped astronomers significantly refine this theory, while also serving to confuse them further. For example, some observations of the 1982–1984 eclipse suggested that the dark companion is a disk that, as it passes in front of the bright star, cuts across its face diagonally. Moreover, the light from the star actually increased by almost two-tenths of a magnitude during the middle of the eclipse, suggesting that this disk is not only semitransparent — but it also has a hole in its center, like a doughnut!

One leading model proposes that the dark companion is a large disk of dust and gas swirling around a single relatively dim star. In this model, the visible star is thought to weigh about 15 solar masses, while the combined weight of the disk and its dim star is 13.7 solar masses.

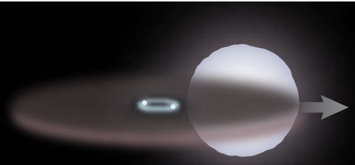
From Earth, we see the disk system nearly edge-on. The disk's estimated diameter is 1.7 billion miles (2.7 billion kilometers), which is almost the size of Uranus' orbit. This theory is especially intriguing because it suggests that the eclipsing object may be a protoplanetary disk — a solar system in the making.

What shapes Epsilon Aurigae's light curve?

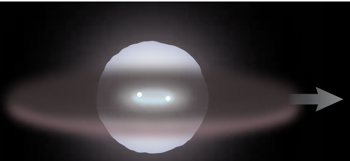
Astronomers think the transit of a huge disk of gas and dust with a central gap can explain Epsilon Aurigae's dimming and brightening. The eclipse lasts about 2 years. *Astronomy*: Roen Kelly



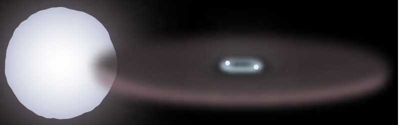
A. As the edge of the disk starts to occult the supergiant primary star, the system's overall brightness starts to decline, as shown on the light curve.



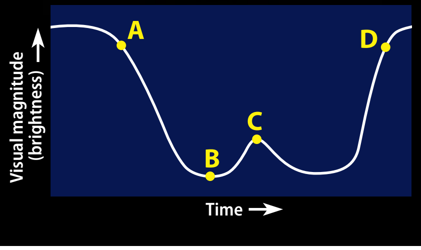
B. At the start of the period of maximum dimming, or "totality," the dense disk covers about one-half of the primary star's face.



C. At mid-eclipse, light peeks through the disk's central gap, causing a slight upturn in brightness.

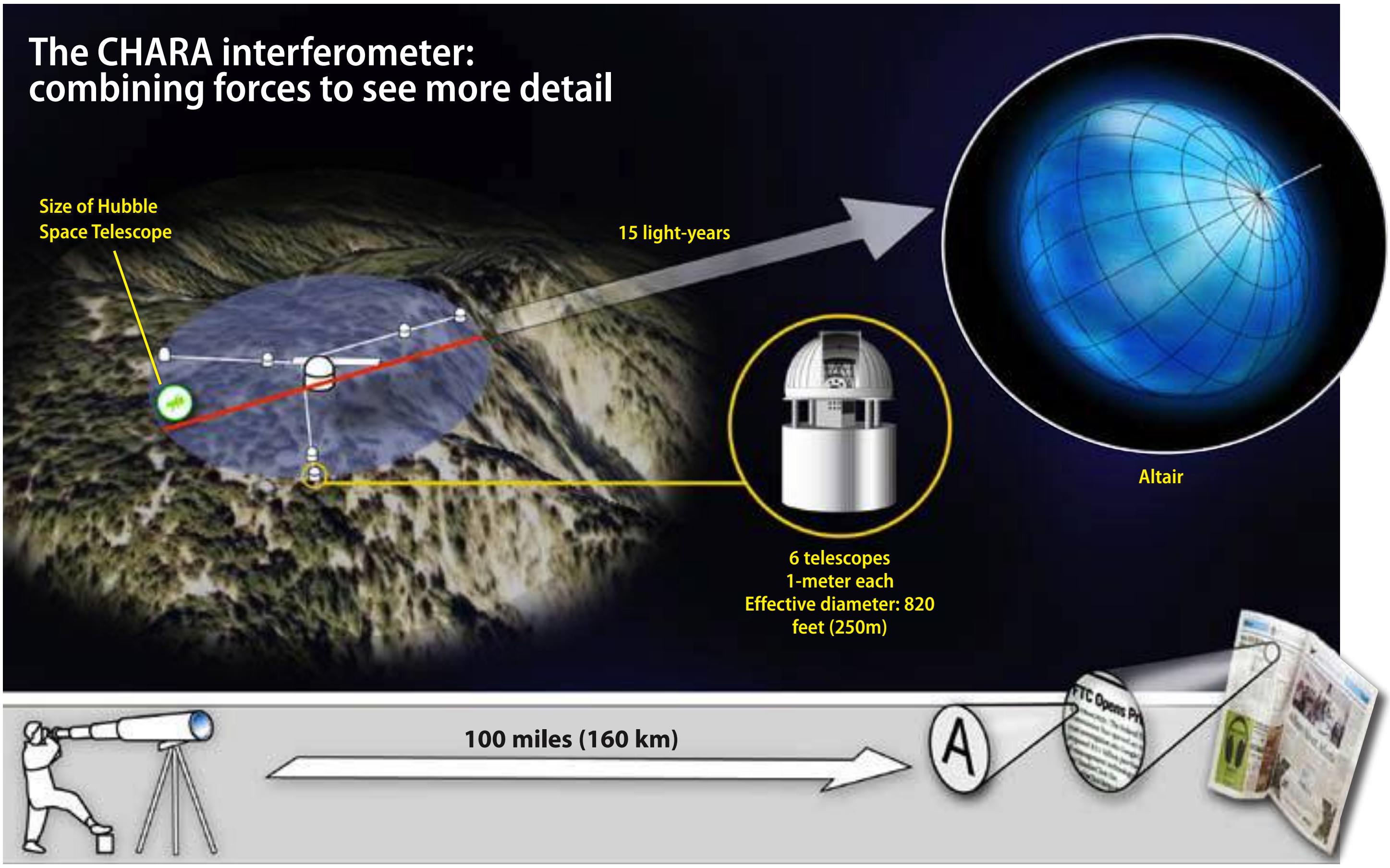


D. The star system returns to normal brightness for another 27 years as the disk's transit comes to an end.



Explanations of Epsilon Aurigae's behavior grew more complicated with further observations. During the 1955–1957 eclipse, the dimming and brightening phases bracketing the eclipse lasted a little more than 4 months each — shorter than in previous eclipses.

Also, the duration of Epsilon Aurigae's minimum brightness, or "totality," was unusually long — about 13 months. Then, the 1982–1984 eclipse accelerated this trend: Totality lasted 15 months, and the final brightening took only 2 months. The findings implied that something in the system was changing.



The Center for High Angular Resolution Astronomy (CHARA) operates an interferometer on Mount Wilson in California. Six 1-meter telescopes observe objects in infrared wavelengths. Combining the telescopes' light yields the detail-resolving power of a single telescope 820 feet (250m) across. Astronomers used the CHARA interferometer to image the star Altair, a feat equivalent to reading a newspaper at a distance of 100 miles (160 kilometers). Zina Deretsky (National Science Foundation)

In 1985, Peter Eggleton, now at Lawrence Livermore National Laboratory in California, and James Pringle of the Institute of Astronomy at the University of Cambridge, England, proposed a new explanation for the observed changes in eclipse timing. For one thing, the researchers downgraded the overall mass of the system. The visible star in their model comes in at only 1.5 to 2.5 solar masses. The disk eclipsing the visible star weighs in at about 5 solar masses and harbors a central pair of stars orbiting each other at a close distance.

Eggleton and Pringle proposed that the visible star is evolving from a red giant to a white dwarf. Over the next 10,000 years, the star will end up as a white dwarf star nestled within shells of gas cast off earlier in its aging process, forming a planetary nebula. As these changes happen, the star actually shrinks, which in turn changes the shape and size of the surrounding cloud. That could explain the changes in the length of totality and the dimming and brightening phases.

In fact, some observations confirm Eggleton and Pringle's story. In October 1977 — between eclipses — astronomers from the University of Tokyo and Kyoto University in Japan detected a sudden change in the radial velocities of the visible star's atmosphere. It was as if the star's outer layers had suddenly experienced a violent and sudden collapse. Additional spectrographic data from the 1982–1984 eclipse also suggested that the system's mass fits the lower numbers of the Eggleton-Pringle hypothesis.

Learn how amateur astronomers can collect valuable data on the eclipse at www.Astronomy.com/toc.

On the other hand, unknown changes taking place in the eclipsing disk rather than the visible star could account for the shifts in timing. "Clearly some trend, some phenomenon, is underway," Stencel notes. And it's happening "on a time scale of decades rather than centuries or millions of years." That means the current eclipse will likely not follow its previous schedule and could hold some new surprises for astronomers.

> Astronomers will attack the latest eclipse with a new and more powerful generation of technology.

New tools

The latest eclipse will be like all the others in one respect: Astronomers will attack it with a new and more powerful generation of technology. This includes, of course, the fleet of modern space observatories such as the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory. All will turn their eyes on Epsilon Aurigae repeatedly.

Of the new detectors, however, possibly the most intriguing are interferometers, which combine the light of multiple ground-based telescopes to enhance their ability to resolve fine details. One such interferometer is an array of six 1-meter telescopes at Mount Wilson in California, which is operated by the Center for High Angular Resolution Astronomy (CHARA) of Georgia State University.

Observing in infrared, the CHARA array produces images with a resolution equivalent to a single telescope with a mirror 820 feet (250m) in diameter. "At this resolution, you could read a newspaper at 100 miles [160 km]," explains John Monnier of the University of Michigan, a frequent user of the CHARA array.

Because there are many ways one can combine the light from CHARA's telescope array, a number of other institutions have developed instruments for it, working in collaboration with Georgia State University. For example, astronomers from the University of Michigan used their Michigan Infrared Combiner (MIRC) to overlay the light from four of CHARA's telescopes to produce the array's first images.

CHARA's spectacular feats have included imaging the surface of several stars and binary systems, such as the rapidly rotating and distorted stars Alderamin and Altair and the mass-exchanging close binary Beta Lyrae. The images of Beta Lyrae are especially dazzling because they show the two stars orbiting each other as well as the gaseous material streaming between them.

CHARA's resolution using MIRC should be able to produce an image of Epsilon Aurigae's eclipsing disk as it transits the face of the star in the current eclipse. "Epsilon Aurigae is an ideal target for us," Monnier says.

The plan is to take a baseline image during the beginning of the eclipse. If the invisible object has a sharp edge and can therefore be imaged, they then will follow up with repeated observations during the entire eclipse.

Citizen scientists

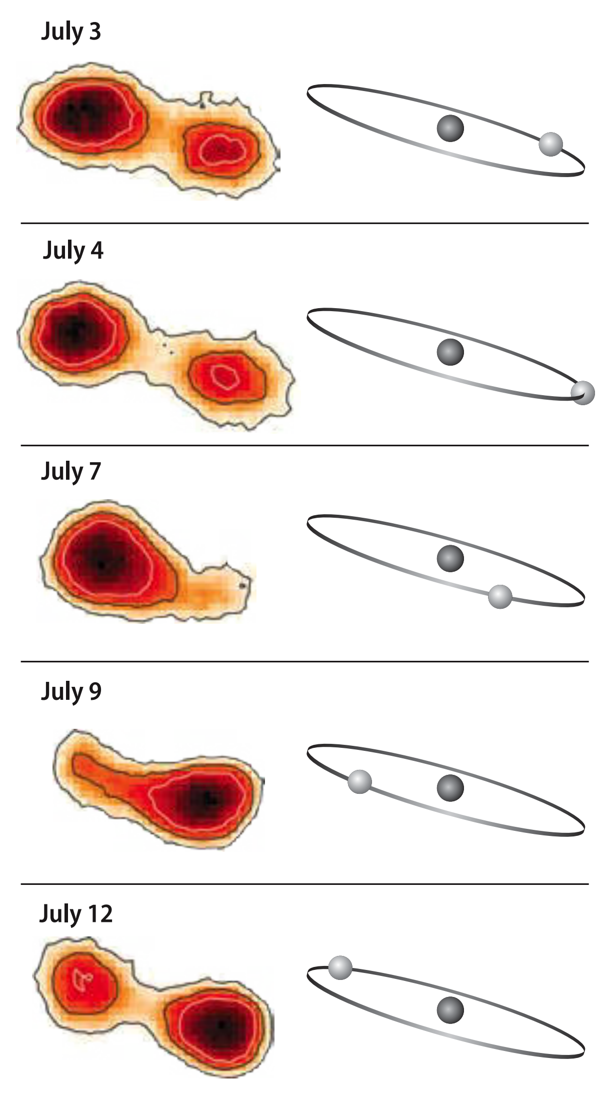
Even as professional astronomers are attacking the problem with the latest technology, amateurs also have an important part to play. For example, since the last eclipse from 1982–1984, retired engineer Jeffrey Hopkins has used his privately built amateur observatory in Arizona to monitor the star. "Jeff is not separately funded for the effort. He does it basically as a hobby," Stencel notes. "Yet I believe his work is professional grade. And you can't beat the persistence factor in his case."

Astronomers hope that other amateurs will join in, monitoring the star daily and tracking its changes in brightness before, during, and after the eclipse. "Weather patterns and time-of-year factors might make it difficult for Jeff to get a complete light curve," explains Stencel. "But if we have people in Canada or Finland watching this thing during high summer, they might be able to help us fill in some blanks." (Epsilon Aurigae's celestial position makes it unobservable at southern latitudes.)

The U.S. component of the International Year of Astronomy 2009 has targeted Epsilon Aurigae for a "citizen scientist" campaign, coordinated by the American Association of Variable Star Observers. Non-professional observers can measure Epsilon Aurigae's brightness telescopically, either with visual methods or using electronic detectors. Those observations will become part of the body of scientific data that astronomers will use to study Epsilon Aurigae.

Hopefully, by the time the eclipse ends in 2011, many gaps will be filled in, and researchers will finally unveil the solution to one of astronomy's most enduring mystery shows. If not, there will always be the next chapter to this story, set to start again sometime around 2046.

CHARA captures the eclipsing binary Beta Lyrae in 2007



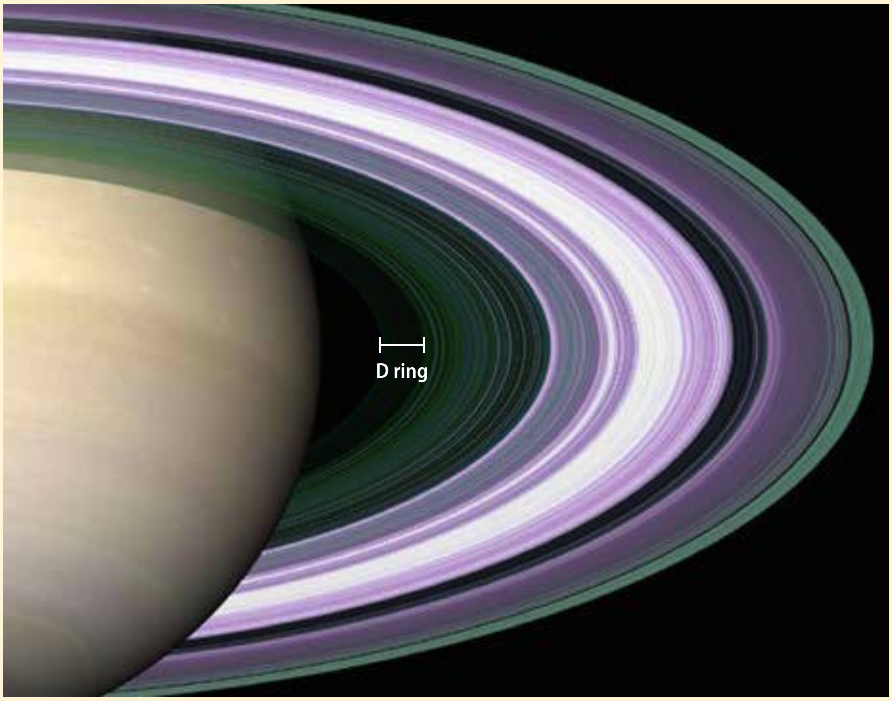
These five images depict the eclipsing binary star system Beta Lyrae as imaged by the Center for High Angular Resolution Astronomy (CHARA) of Georgia State University. Working in tandem, CHARA's six telescopes produced the first-ever images of an eclipsing binary star system, in which one of the pair periodically eclipses the other and causes a slight dimming. Beta Lyrae contains two stars orbiting so close that gaseous material flows from one sun to the other. In these images, the darker component of each pair is the gas donor. Astronomers hope the CHARA telescopes may reveal similar detail in the Epsilon Aurigae system. *Astronomy*: Roen Kelly; CHARA images by Ming Zhao (University of Michigan)

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

Saturn's elusive ring particles

Q: Saturn's rings are said to contain chunks of icy debris as big as cars. Why are none of the larger particles visible in the Cassini photos? — **Roy Bettenhausen,** Tracy, California



Probing Saturn's rings with radio waves revealed particle sizes. Purple indicates areas populated predominantly by ring particles larger than 2 inches (5 centimeters). Green areas have a significant number of particles smaller than 0.4 inch (1 cm). White indicates a portion of the ring system too dense with particles to measure. RSS/JPL/ESA/NASA

A: The largest ring particles appear to be about 10 feet (3 meters) across. The smallest are mere dust grains. **At the distances Cassini orbits Saturn, its cameras are not sharp enough to capture images of even the largest particles in Saturn's rings.**

Cassini maintains a safe distance from the rings to prevent collisions with particles. An impact with even a small particle could be fatal to the craft. But the distance imposes limits on resolution — the smallest detail visible to Cassini's telescopic Narrow Angle Camera (NAC).

In 2004, when Cassini first arrived at Saturn, its closest approach to the rings was about 9,900 miles (16,000 kilometers). At that distance, the NAC couldn't resolve anything smaller than about 330 feet (100m) across. That's more than 30 times the size of the largest ring particle.

By 2016, planned tweaks to Cassini's orbit will bring the probe within a few hundred miles of Saturn's innermost D ring. Even at this distance, Cassini is not likely to image large debris fragments because the D ring mostly contains dust-sized particles. — **William B. McKinnon,** Washington University in St. Louis

STAR DEATH

Q: When a star in a binary system goes supernova, what happens to its companion? Is it destroyed? — **Mitch Singer,** Minneapolis

A: In a binary system, two stars orbit their common center of mass. **If one of the stars explodes in a supernova, its companion would likely survive the blast.**

Typical middle-aged stars, such as the Sun, are pretty tough. Most of the mass in such stars is concentrated toward the center. Even a nearby catastrophe like a supernova will blast off only a small fraction of a star's outer layers — perhaps 10 percent or less of the total mass.

Aged red giant stars could suffer greater losses. In these suns, gravity only weakly binds the outer layers to the main body of the star. A supernova would easily strip off most of this gaseous envelope. Even so, the star's small, dense core would survive.

Some stars are completely destroyed during a supernova. In this case, the surviving star would fly off on its own into space. If the supernova transforms the original star into a compact remnant, such as a black hole or superdense neutron star, the outcome varies.

If half or more of the two stars' combined mass is left, the surviving star and the compact remnant would remain bound by gravity and continue to orbit each other. If more than half the mass is lost, they may go their own ways.

Another possible outcome is that the supernova explosion delivers a strong "kick" of momentum to the compact remnant it creates, ejecting it into interstellar space. — **J. Craig Wheeler,** Department of Astronomy, University of Texas at Austin

TELESCOPE TECH

Q: **I read somewhere that mercury is being used to make liquid-mirror telescopes. What are the advantages of collecting light this way?** — **Ron Goedert,** Bethel Park, Pennsylvania

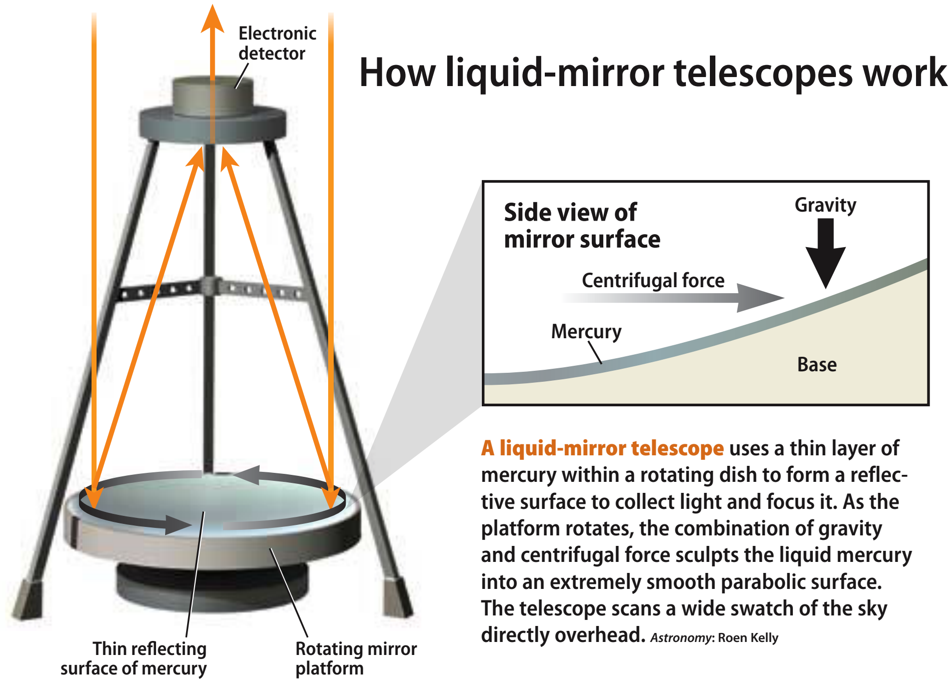
A: The idea of a liquid telescope mirror dates back more than a century. The principle is simple: If you rotate a dish of liquid, the combination of centrifugal and gravitational forces causes the surface of the liquid to take on a concave shape. If the rotation speed is constant, this surface forms a parabola and can be used to focus light. Liquid-mirror telescopes use mercury because it's highly reflective and remains liquid at temperatures above −38.2° Fahrenheit (−39° Celsius).

The main advantage of a liquid-mirror telescope is its low cost compared to a conventional telescope with a glass mirror. For mirrors with diameters of several meters or more, the cost savings are significant. This makes liquid-mirror telescopes an attractive option for large astronomical survey programs. The most powerful liquid-mirror telescope constructed so far is the 6-meter Large Zenith Telescope, located near Vancouver, British Columbia.

One disadvantage of liquid-mirror telescopes is their limited maneuverability. Because the axis of rotation of a liquid mirror must remain vertical, these telescopes can observe only a region of sky directly overhead.

However, as Earth rotates, the celestial sphere passes overhead. This enables these telescopes to observe many square degrees of the sky and, potentially, millions of stars and galaxies. — **Paul Hickson,** University of British Columbia, Vancouver

How liquid-mirror telescopes work



A liquid-mirror telescope uses a thin layer of mercury within a rotating dish to form a reflective surface to collect light and focus it. As the platform rotates, the combination of gravity and centrifugal force sculpts the liquid mercury into an extremely smooth parabolic surface. The telescope scans a wide swatch of the sky directly overhead. *Astronomy*: Roen Kelly

THE BLACK HOLE REVOLUTION

Q: **Do black holes and their accretion disks always spin in the same direction? Does a supermassive black hole always spin in the same direction as its host galaxy?** — **Shanita Andrews,** Baltimore

A: As matter falls toward a black hole, it forms a spinning, whirlpool-like accretion disk. Gravity forces the infalling gas to rotate around the same axis as the black hole itself. **The disk can rotate either clockwise or counterclockwise relative to the black hole.**

The same is true for the direction black holes rotate: They can spin either clockwise or counterclockwise. Astronomers have seen no evidence that black holes have "handedness," meaning they tend to spin one way or the other.

Most large galaxies appear to host central supermassive black holes. We can tell which direction such black holes spin by observing the jets of matter and energy they expel in opposite directions.

Theoretical studies indicate the jets align parallel to the spin axis of the black hole that generates them and also rotate in the same direction. But when we observe galaxies, it's clear that they and their supermassive black holes don't necessarily rotate in the same directions.

— **Eliot Quataert,** Theoretical Astrophysics Center, University of California at Berkeley

SPACE ROCK RECIPE

Q: **What are asteroids made of?** — **James Vitello,** Hamden, Connecticut

A: **Asteroids, leftover remnants from the formation of the solar system, are composed of rock, metal, or a combination of both.**

Most asteroids are primarily rocky bodies containing silicate minerals. All silicate minerals contain silicon bonded with oxygen, but they usually include other elements in their crystal structure, such as iron and magnesium.

A smaller proportion of asteroids are primarily metallic, containing mostly iron and nickel. Some asteroids are combinations of silicates and metals. Asteroids can also contain organic molecules, such as amino acids.

Scientists have learned a lot about asteroid compositions from studying meteorites — chunks of asteroids that enter Earth's atmosphere and reach the surface intact. It's also possible to study asteroids still in space by breaking their reflected light into its component wavelengths, or spectrum. This spectral "fingerprint" contains clues to an asteroid's chemical composition because each mineral usually reflects light differently.

Additional information about asteroid composition comes from spacecraft. In 2000, for example, NASA's Near Earth Asteroid Rendezvous-Shoemaker (NEAR Shoemaker) mission visited the asteroid 433 Eros. NEAR's suite of instruments mapped Eros' surface in detail and collected data on its chemical composition. — **Thomas H. Burbine, Jr.,** Bates College, Lewiston, Maine

Find out what happens to matter in a black hole at www.Astronomy.com/toc.

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Take the Ghost Hunt challenge

This Halloween season, grab your telescope and scare up these spooky objects. **by Stephen James O'Meara**

Each spring, amateur astronomers around the world challenge themselves by competing in the Messier Marathon — a visual feat in which observers use their telescopes to view all 109 celestial objects catalogued by French comet-hunter Charles Messier in a single night. This dusk-to-dawn romp has been a popular annual event since the 1960s. The search is fun and gratifying, and it helps observers hone their hunting skills.

Why not double the fun by hosting a similar challenge in the autumn? I have created a list of 109 deep-sky objects that you can hunt down in a single night on or around the New Moon closest to Halloween. In deference to the time of year, and considering that many deep-sky objects appear as pale specters of fuzzy light, I decided to call this October treat the Ghost Hunt.

Like the Messier Marathon, the Ghost Hunt is intended to be a fun and challenging activity that lasts from dusk to dawn. But there's one big difference: What you'll search for in the Ghost Hunt are not just Messier objects but 109 targets carefully selected from several deep-sky object lists.

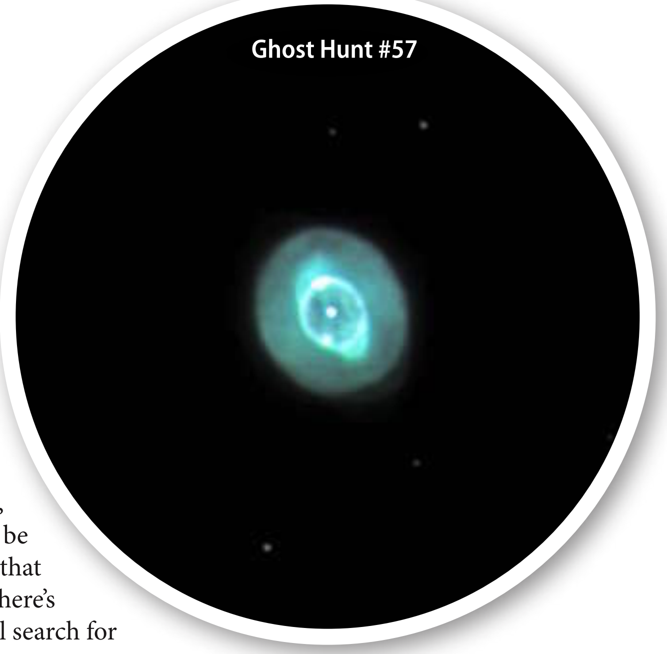
109 spooky objects

The Ghost Hunt features 25 open star clusters, 27 galaxies, 16 emission nebulae, four reflection nebulae, 19 planetary nebulae, 14 globular star clusters, three supernova remnants (including two segments of the Veil Nebula), and one dark nebula. While nearly 70 percent of the objects in the Ghost Hunt are not Messier objects, they should be no more challenging to see.

Even the most southerly object (#50 on the list — emission nebula NGC 2467 in Puppis) stands 8° higher in the sky than the most southerly Messier object (M7 in Scorpius). When NGC 2467 is highest in the sky, it sits nearly 20° above the horizon from a latitude of 45° north.

If you peruse the list, you'll find some of the night sky's already famous ghosts: #10, Mirach's Ghost (NGC 404); #57, the Ghost of Jupiter (NGC 3242); and #101, the Ghost of Saturn (NGC 7009). The list also includes several other spooky favorites: #11, the Owl Cluster (NGC 457); #14, the Phantom Galaxy (M74); #19, the Outer Limits Galaxy (NGC 891); and #62, the Flying Witch Cluster (Mel 111).

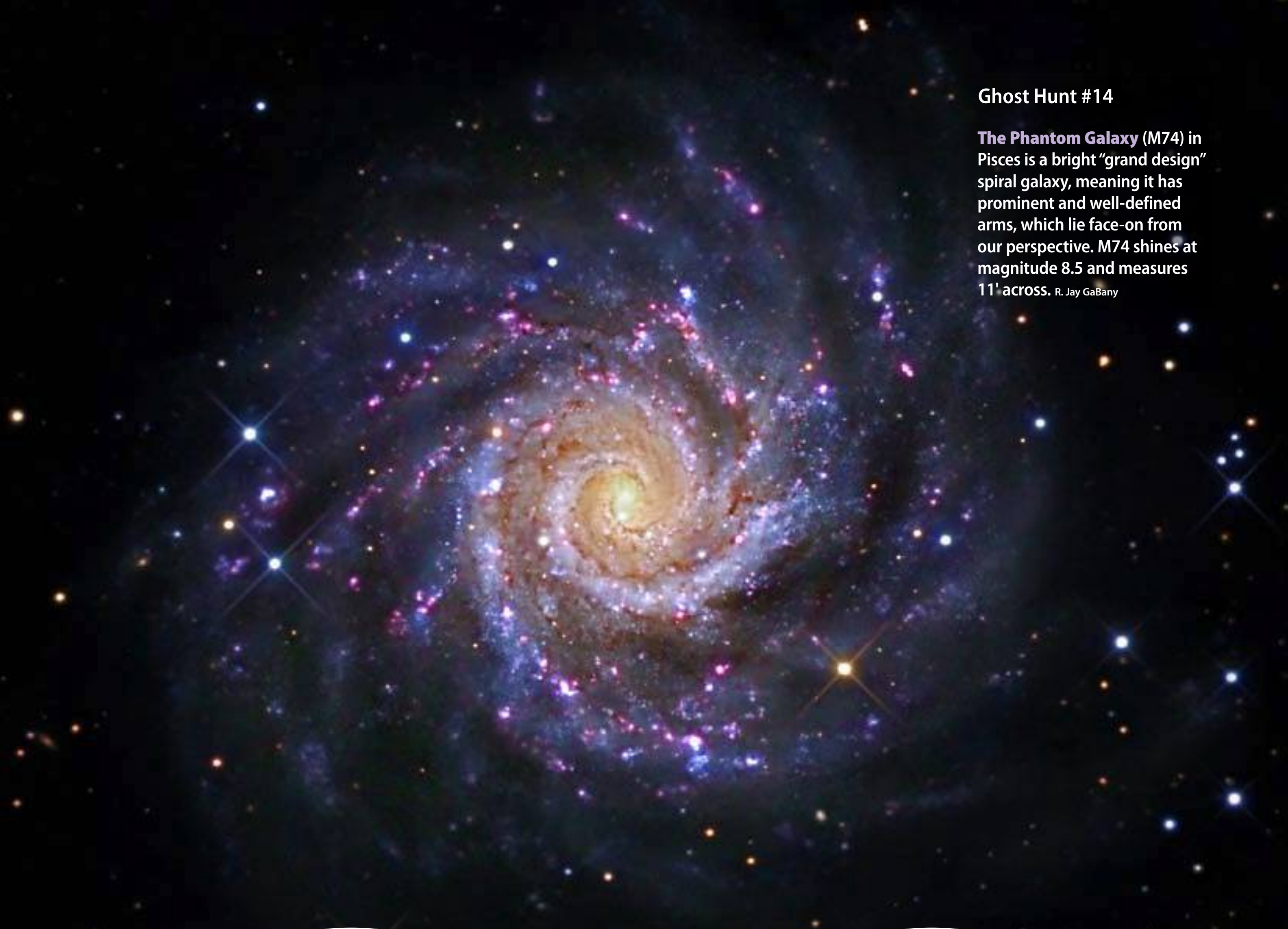
I took great pains to choose objects that are visible through small- to medium-sized telescopes under either a



The Ghost of Jupiter (NGC 3242) has the perfect name for an object on the Ghost Hunt. This planetary nebula sits in west-central Hydra about 35° south of Leo the Lion. At low magnification through a 6-inch telescope, you'll see NGC 3242's pale blue-green disk. Through larger scopes, and at powers above 200x, the interior appears oval, like an eye or a football. Adam Block/NOAO/AURA/NSF

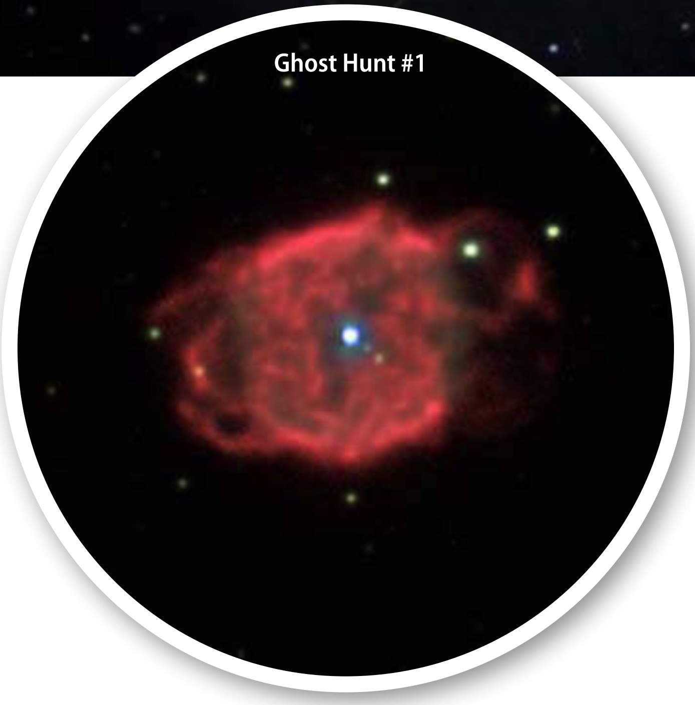
Ghost Hunt #109

The Screaming Skull (NGC 7789) is a concentrated open star cluster in Cassiopeia. You'll find it a little less than 3° south-southwest of magnitude 2.3 Caph (Beta [β] Cassiopeiae). NGC 7789 shines at magnitude 6.7 and measures 15' across. Lee C. Coombs



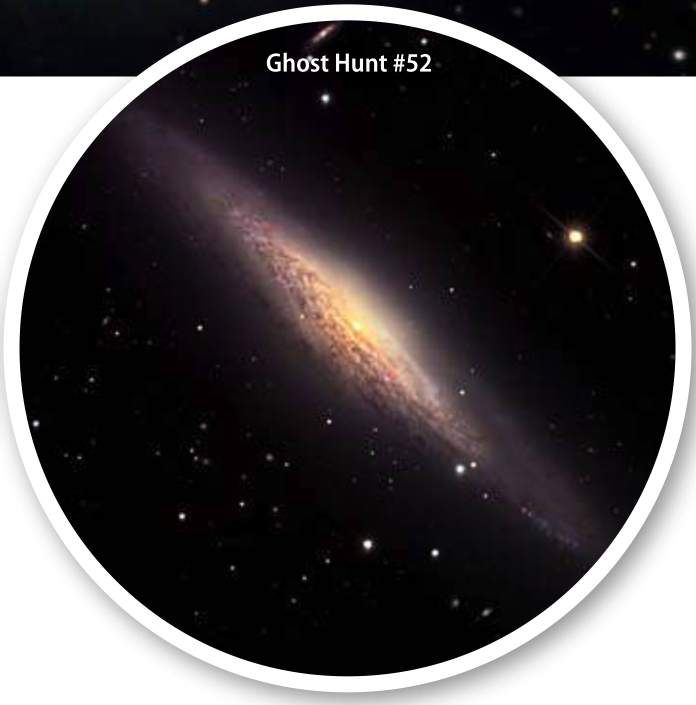
Ghost Hunt #14

The Phantom Galaxy (M74) in Pisces is a bright "grand design" spiral galaxy, meaning it has prominent and well-defined arms, which lie face-on from our perspective. M74 shines at magnitude 8.5 and measures 11' across. R. Jay GaBany



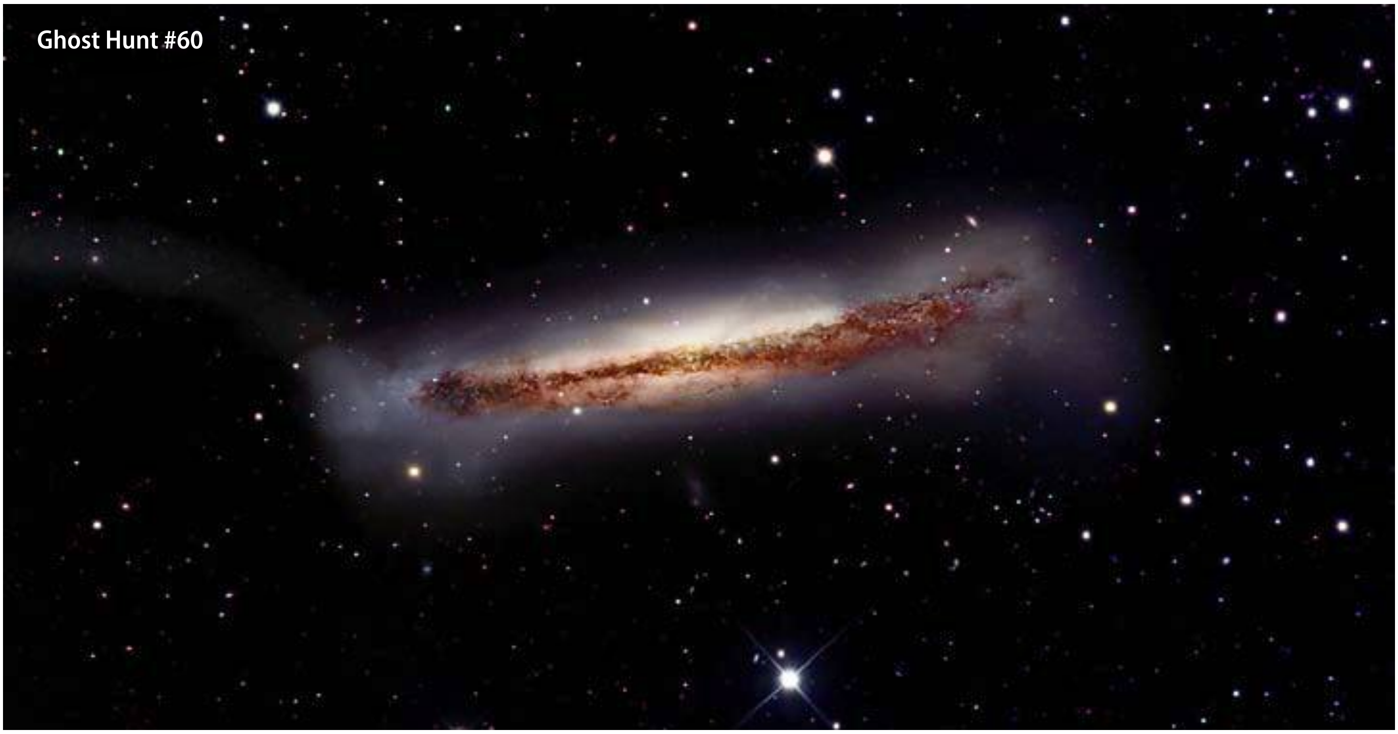
Ghost Hunt #1

The Bow-Tie Nebula (NGC 40) is the faintest object on the Ghost Hunt list. Luckily, its surface brightness is high, so you won't have any trouble observing it even through a 4-inch telescope. A magnification around 100x works best. Steve and Paul Mandel/Adam Block/NOAO/AURA/NSF

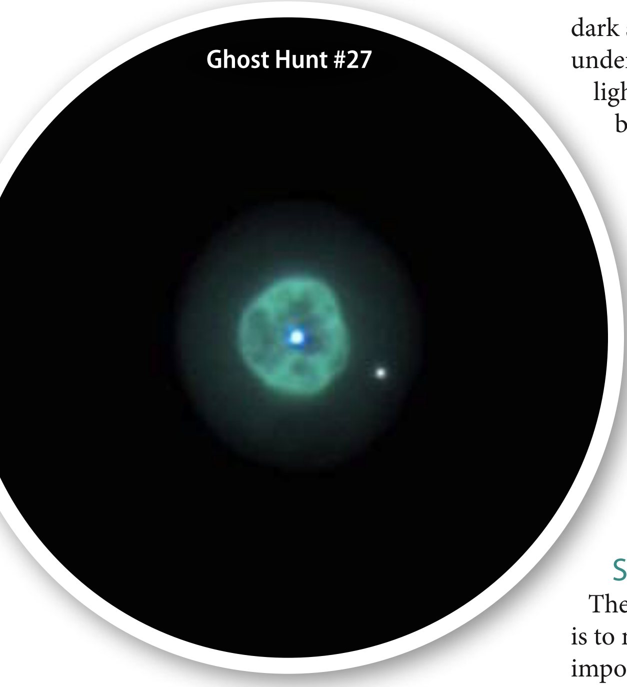


Ghost Hunt #52

The UFO Galaxy (NGC 2683) is a magnitude 9.8 spiral galaxy in Lynx that we view edge-on. Astronomers peg its distance at a relatively close 16 million light-years. Doug Matthews/Adam Block/NOAO/AURA/NSF



King Hamlet's Ghost (NGC 3628) is a beautiful edge-on spiral galaxy that features a wide, dark dust lane. This galaxy resides in Leo and travels through space with two of Messier's bright galaxies: M65 and M66. NGC 3628 lies about 0.6° north of that well-known pair. Keith B. Quattrocchi



Cleopatra's Eye (NGC 1535) lies 4° east-northeast of magnitude 3.0 Zaurak (Gamma [γ] Eridani). The planetary is nice and bright, and it takes high powers well. Through a 6-inch telescope, NGC 1535 has a sharply defined disk surrounded by a faint envelope. Double that aperture to 12 inches, and you'll begin to pick up this object's color. Adam Block/NOAO/AURA/NSF

dark sky or (except for the galaxies) under a suburban sky with the aid of light-pollution reduction filters. The brightest object in the Ghost Hunt is #25, the Pleiades star cluster (M45) in Taurus, which shines at magnitude 1.5. The faintest object on the list is the first entry, the Bow-Tie Nebula (NGC 40), which glows at magnitude 12.3. But as skilled observers know, magnitudes alone can be deceiving. NGC 40 is easier to see than some Messier objects because it is small and condensed.

Scare up a plan

The key to success in any competition is to make a plan and stick to it. It's important to pace yourself. Start by looking at the objects that are closest to setting as night falls. Then consider which objects you think will be easiest to find, and go after them first.

I suggest categorizing the objects into groups and moving from group to group south to north (or vice versa). You can work your way progressively eastward until dawn.

Everyone will want to tackle the bright nebulae M16 (#76) in Serpens and M17 (#77) in Sagittarius first because they're low in the southwest after sunset. Then keep searching this section of sky for other objects on the list because none of them will return to the morning sky.

Several targets low in the northwestern sky at dusk — such as the galaxies M82 (#56) and M101 (#71) in Ursa Major — appear much higher in the northeastern sky before dawn. And if you happen to miss globular clusters M13 (#72) or M92 (#73) in Hercules, they will reappear low in the northeastern sky before dawn.

The lowest, most southerly predawn object will be the Ghost of Jupiter (NGC

Ghost Hunt #92

Mothra (NGC 6940) is an open star cluster whose brightest stars form a figure that resembles a moth — or the fantastic creature in the Godzilla pantheon that made its movie debut in 1961. NGC 6940 shines at magnitude 6.3 and measures 31' across — the same diameter as the Full Moon. Anthony Ayiomamitis

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Stephen James O'Meara *is a contributing editor of* Astronomy *who writes the monthly column "Secret Sky."*

Ghost Hunt #19

Spiral galaxy NGC 891 ranks as one of the sky's best edge-on galaxies. Its problem is that it's only the constellation Andromeda's second-best galaxy. That star pattern's top dog happens to be one of the sky's supreme wonders — the Andromeda Galaxy (M31). NGC 891 inclines only 1.4° to our line of sight. Ken Crawford

Ghost Hunt #48

The Intergalactic Wanderer (NGC 2419) has that name because of its extreme distance from Earth. Astronomers' recent studies show that it lies 275,000 light-years away. The bright star nearest the cluster shines at magnitude 7.2 and lies only 4' from NGC 2419. Doug Matthews/Charles Betts/Adam Block/NOAO/AURA/NSF

3242 — #57) in Hydra, but even it is fairly well-positioned above the horizon.

Spirited public events

As with the Messier Marathon, friends or club members can join together in the hunt. It's also a good event for astronomy clubs, museums, and societies.

Why not host a costume star party for the public with telescopic observing? Take advantage of the fuzzy appearance of some of these deep-sky objects, and help people get interested in our hobby at a time of year when we all yearn for ghost sightings. Be creative in your approach. To inspire kids, you can refer to your telescopes as "ghost catchers" and your filters as special "ghost viewers." Just have some fun at a time of year when most people expect treats.

I described in my October 2008 "Secret Sky" column Samhain (pronounced souw'-in), the most sacred witch's sabbat. It starts with the midnight culmination (when an object sits at its highest point in the southern sky) of the Pleiades (M45 — #25) on October 31. On this mystical evening, which later became known as All Hallow's Eve, the veil separating the living from the dead became transparent, which allowed the two groups to communicate. I am not suggesting that the public is "dead," but I do think the Ghost Hunt is a good way to open up channels of communication and show groups some of the dynamic wonders in the night sky.

If you target a bright planetary nebula like the Ring Nebula (M57 — #83) in Lyra or a supernova remnant such as the Veil Nebula (NGC 6992/5 — #95) in Cygnus (both of which are high in the sky after dusk), you can teach your guests about the different life cycles of stars. The Veil exemplifies the demise of a single supergiant star, while the Ring reflects the ultimate fate of stars like our Sun.

Not just phantom dates

This year, the New Moon falls on October 18, a Sunday. So that weekend would be the best time to hold a Ghost Hunt. The weekend beginning Friday, October 23 is also good because the Moon is still a waxing crescent that sets around 10 P.M. local time. It shouldn't affect your view of the objects on the list.

As your guests admire the Ghost Hunt's sights, explain to them how, owing to the vastness of space and the limited speed of light, we can travel back in time by simply looking up at the night sky. When it comes to astronomy, the past is very much alive. And it will remain so far into the future.

10 choice selections from the Ghost Hunt

Here are the statistics for the images pictured so you can warm up your telescope. Subscribers can find the whole list online to download or print at www.Astronomy.com/toc.

	Designation	Type	Con.	R.A.	Dec.	Mag.	Size	Common name
#57	NGC 3242	PN	Hya	10h25m	–18°39'	7.8	45" by 36"	Ghost of Jupiter
#109	NGC 7789	OC	Cas	23h58m	56°43'	6.6	25'	Screaming Skull
#14	M74	Gal	Psc	1h37m	15°47'	8.5	10.5' by 9.5'	Phantom Galaxy
#1	NGC 40	PN	Cep	0h13m	72°31'	12.3	38" by 35"	Bow-Tie Nebula
#52	NGC 2683	Gal	Lyn	8h53m	33°25'	9.8	9' by 3'	UFO Galaxy
#60	NGC 3628	Gal	Leo	11h20m	13°35'	9.5	15' by 3'	King Hamlet's Ghost
#27	NGC 1535	PN	Eri	4h14m	–12°44'	9.1	48" by 42"	Cleopatra's Eye
#92	NGC 6940	OC	Vul	20h35m	28°17'	6.3	31'	Mothra
#19	NGC 891	Gal	And	2h32m	42°21'	9.9	12' by 3'	Outer Limits Galaxy
#48	NGC 2419	GC	Lyn	7h38m	38°53'	10.4	5'	Intergalactic Wanderer

Key: Con. = Constellation; R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mag. = Visual magnitude; DN = Dark nebula; EN = Emission nebula; Gal = Galaxy; GC = Globular cluster; OC = Open cluster; PN = Planetary nebula; SNR = Supernova remnant

Download or printout a PDF file of the entire list at www.Astronomy.com/toc.

Explore 12 great lunar targets

Sharpen your observing skills on the Moon's craters, lava flows, and an elusive letter X.

by Michael E. Bakich

The Moon offers something for every observer. It has a face that's always changing. Following it telescopically through a lunar month can be fascinating.

Ironically, when the Moon is brightest (Full Moon) is the worst time to view it. From our perspective, the Sun is shining on the Moon from a point directly behind us, minimizing shadows and thus revealing scant detail.

The best lunar viewing times are from when the thin crescent becomes visible after New Moon until about 2 days after First Quarter (evening sky) and from about 2 days before Last Quarter to almost New Moon (morning sky). Shadows are longer then, and features stand out in sharp relief.

This is especially true along the Moon's shadow line — called the terminator — which divides the light and dark portions. Before Full Moon, the terminator shows where sunrise is occurring; after Full Moon, it marks the sunset line.

Along the terminator, you'll see mountaintops protruding high enough to catch sunlight while the dark lower terrain surrounds them. On large crater floors, you can follow "wall shadows" cast by sides of craters hundreds of feet high. All these features seem to change in real time, and the differences you can see in one night are striking.

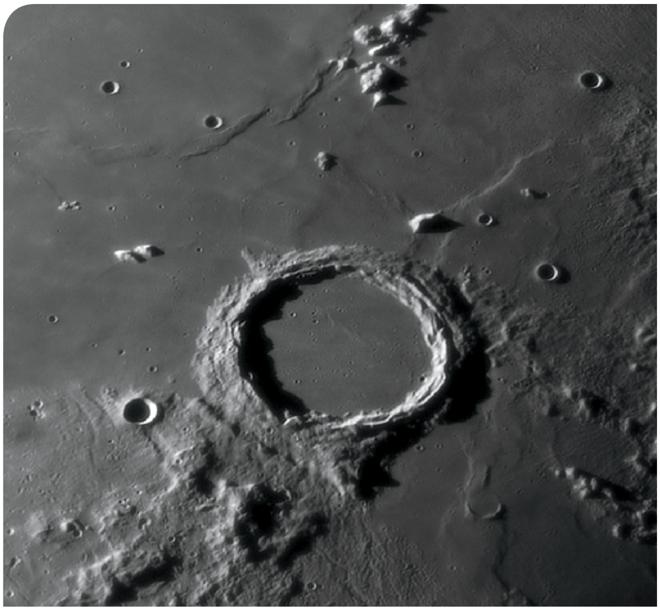
The Moon orbits Earth approximately every 27.3 days. Because Earth also orbits the Sun, the Moon and Sun line up roughly every 29.5 days. The changing positions of the Moon with respect to the Sun cause the Moon, as seen from Earth, to cycle through a series of phases. One complete set of phases is a lunar month. By definition, the lunar month begins at New Moon. We can't see New Moon from Earth because, at that time, the Moon's lit side faces the Sun. The Moon then is also quite near the Sun in the sky.

Observing tips

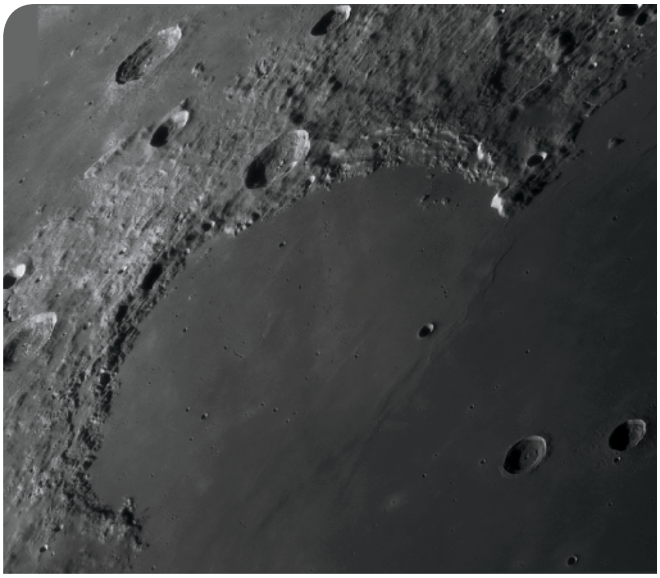
The Moon is a brilliant object through a telescope. Many observers employ either neutral density filters or variable polarizing ones to reduce the light. I prefer the latter because you can change the amount of light filtered.

My late observing friend, Jeff Medkeff, introduced me to a better way, however. Turn on a white light when observing the Moon between First Quarter and Full. The addition of light suppresses the eyes' tendency to dark adapt and causes the eye to use normal (scotopic) vision, which is of much higher quality than dark-adapted (photopic) vision.

Lunar observers usually don't use color filters. However, I do have some friends who have noted a darkening of the lunar basalt when they use a red filter. A red filter also can help



1 **Archimedes Crater** lies at 30° north latitude centered between the eastern and western limbs. This 52-mile-wide (83 kilometers) impact crater lies just northwest of the Moon's largest mountain range, the Montes Apenninus. Through an 8-inch or larger telescope, scan Archimedes' floor for a large number of craterlets. For the best view of this crater, observe around First Quarter. North is up in all images. Alan Friedman



2 **Sinus Iridum,** the Bay of Rainbows, on the Moon's northwestern edge, spans a whopping 162 miles (260 km). Flanking Sinus Iridum to the north is the C-shaped mountain range Montes Jura. Numerous craterlets dot Sinus Iridum's remarkably flat surface. The largest is Laplace A, named for Laplace Promontorium, the bright point that terminates the top of the "C." Alan Friedman

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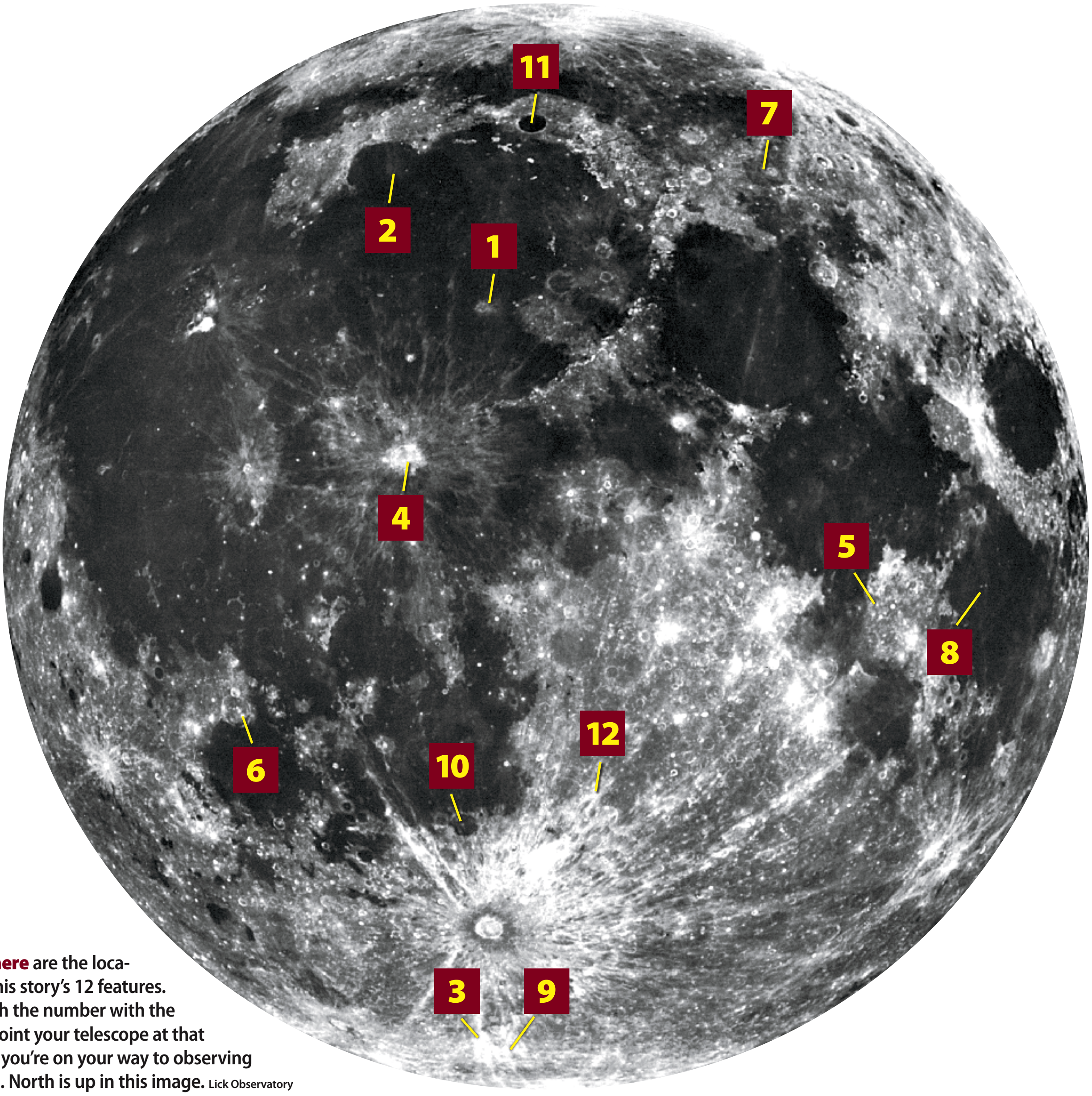
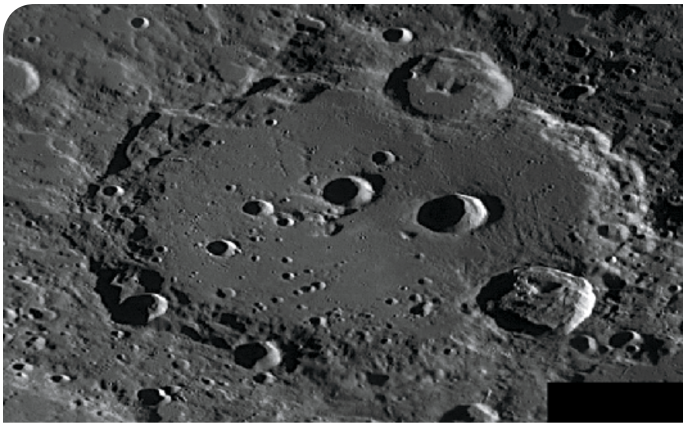
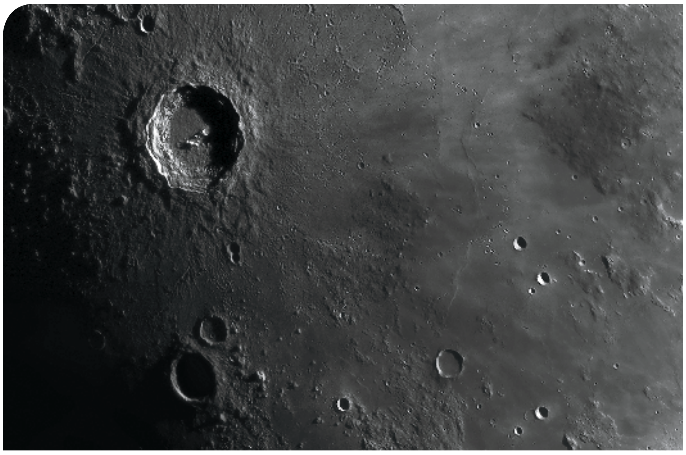
Michael E. Bakich *is a senior editor of* Astronomy.



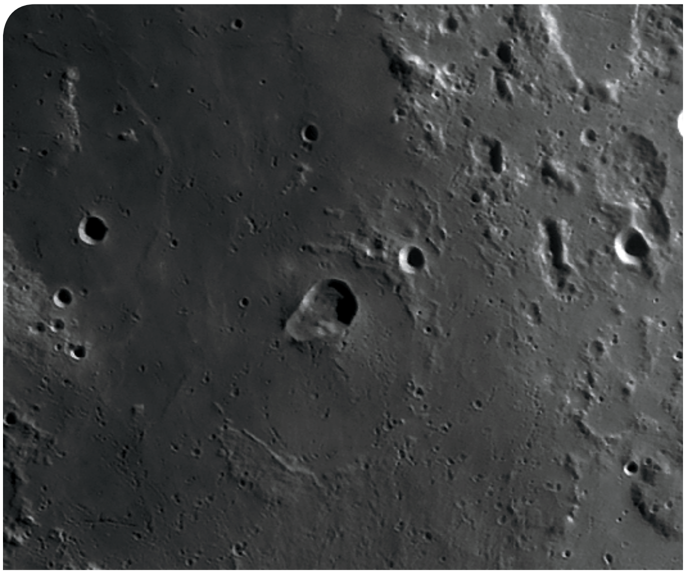
Plotted here are the locations of this story's 12 features. Just match the number with the picture, point your telescope at that spot, and you're on your way to observing the Moon. North is up in this image. Lick Observatory



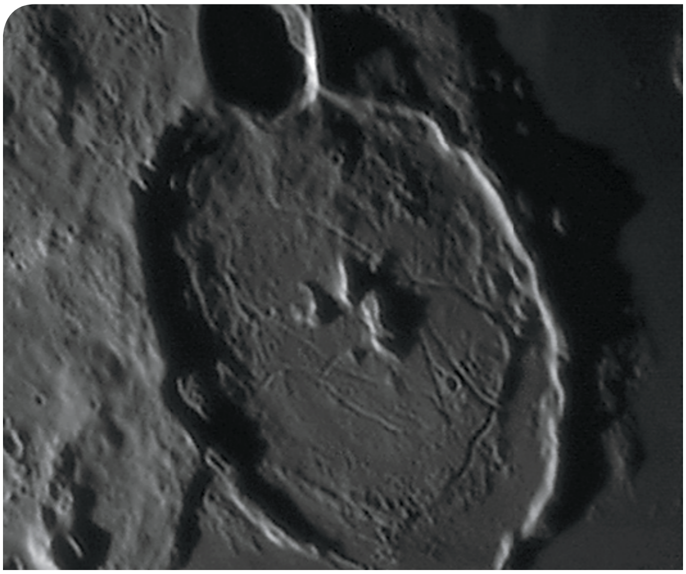
3 **Clavius Crater** ranks as the third-largest crater on the Moon's nearside. It's visible to the naked eye and spans 140 miles (225 km). But it's what's in Clavius that I suggest you observe. Look for the crater chain of decreasing size that begins at Clavius' eastern wall. Oblong Rutherfurd Crater measures 33.5 miles by 30 miles (54 km by 48 km). Following it are Clavius D (17 miles [28 km]), C (13 miles [21 km]), N (8 miles [13 km]), J (7.5 miles [12 km]), and JA (5 miles [8 km]). In addition to those, numerous craterlets that will test any size telescope dot Clavius' floor. David Tyler



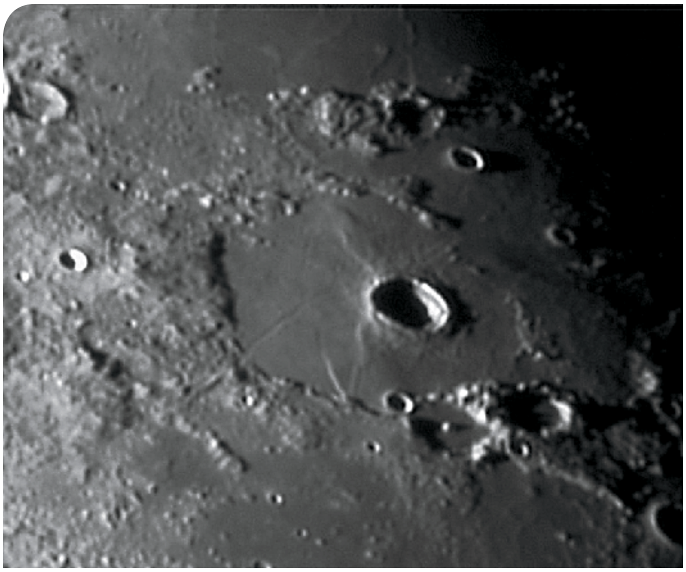
4 **Copernicus Crater** is one of the Moon's most famous formations. This impact marks the center of a system of bright rays that extends for up to 500 miles (800 km). Copernicus measures 58 miles (93 km) wide. Because of its great depth — 12,300 feet (3,750 meters) — sunrise and sunset shadows here create dramatic relief. The central peak rises 3,940 feet (1,200m) above the crater's floor. Copernicus' outer wall gives it a peculiar hexagonal shape. Paolo Lazzarotti



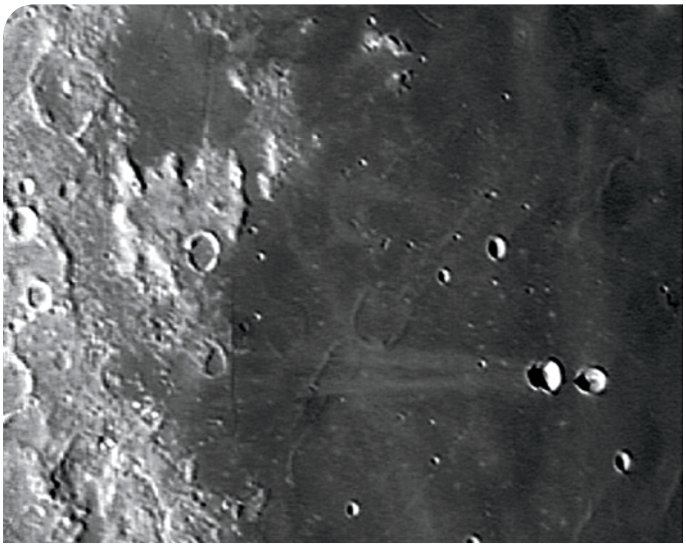
5 **Torricelli Crater** appears pear-shaped at first glance because its western wall is open and connects to a smaller crater. Both structures lie in the upper part of a low-contrast circular formation named Torricelli R. The prominent crater to the east is 6.8-mile-wide (11 km) Torricelli A. Torricelli Crater measures 14.3 miles (23 km) across. Paolo Lazzarotti



6 **Gassendi Crater,** whose long axis measures 68 miles (110 km) across, is a spot that will hold your attention. Numerous clefts, hills, and central mountains interrupt its floor. To the north, the crater designated Gassendi A has broken its wall. Together, both craters give the appearance of a diamond ring, especially at low magnification. Alan Friedman



7 **Lacus Mortis,** the Lake of Death, spans 93 miles (150 km) and lies in the Moon's northeastern quadrant. It contains the 25-mile-wide (40 km) crater Bürg. Try to spot the rilles to the west (left in this image) of Bürg, which run for some 60 miles (100 km). Lunar cartographers designated these collectively as Rimae Bürg. Damian Peach



8 **Messier and Messier A** are two small craters that sit on the Moon's eastern side only 2° south of its equator. Messier is an oblong crater measuring 5.6 miles by 6.8 miles (9 km by 11 km). Messier A spans 8.1 miles by 6.8 miles (13 km by 11 km). Two linear rays extend westward from Messier A for more than 60 miles (100 km). If your sky is steady, look for the thin rille Rima Messier, which lies to the northwest of the craters. Anthony Ayiomamitis

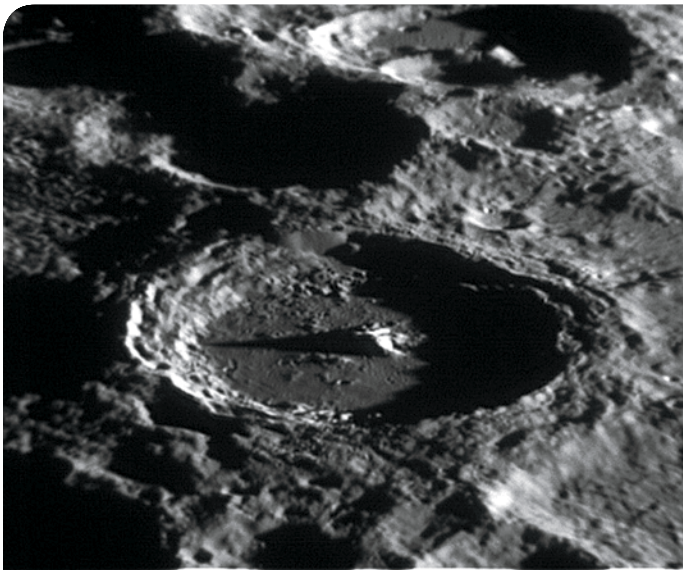
improve the view when the atmosphere is unsteady. It reduces the Moon's brightness as well.

Two other methods can reduce the Moon's brightness: high magnification and an aperture mask. The first restricts the field of view to a small area of the lunar surface and reduces light throughput. The second is a cardboard mask with a smaller hole cut out of it. Cover the front of your telescope with it, and it will transform your telescope into one of smaller aperture (letting less light through), but with the same focal length.

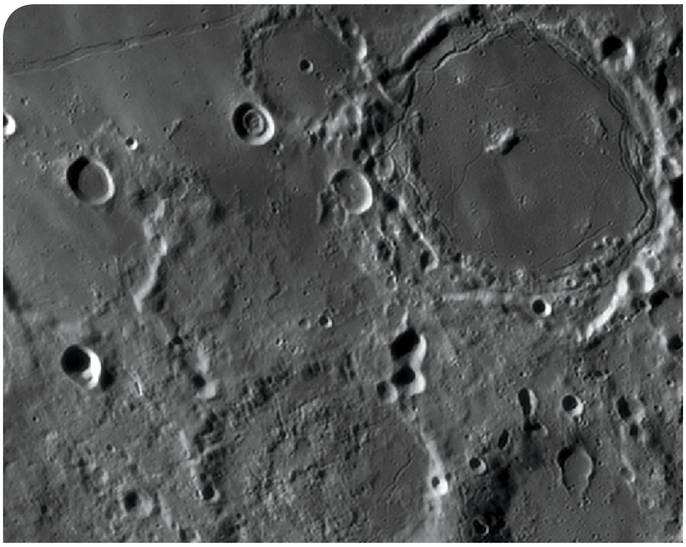
Lunar cartographers differentiate features on the Moon as lighter areas called "highlands" and darker features called "maria" (the Latin word for "seas" [singular = mare]). The maria are lower in altitude than the highlands. The dark material inside the maria is solidified basaltic lava from periods of volcanism up to about a billion years after the Moon formed.

Essentially, anything not covered by lunar basalt is a highland. The highlands consist of ancient lunar surface rock and materials thrown out during the explosive impacts that formed the basins. The highlands are an observer's treasure trove of mountains and valleys, bright areas and shadows.

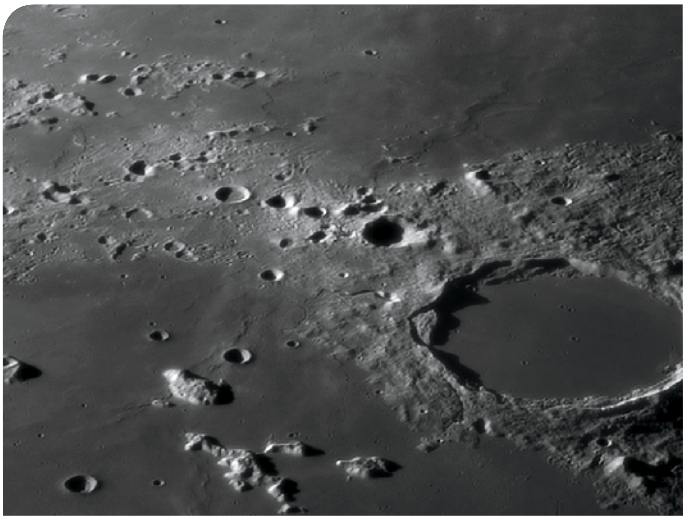
Of the 1,940 named features on the Moon, astronomers classify 1,545 (nearly 80 percent) as craters. Many more craters dot the highlands than maria sites. Craters range in size, and some observers challenge themselves by either noting how small a



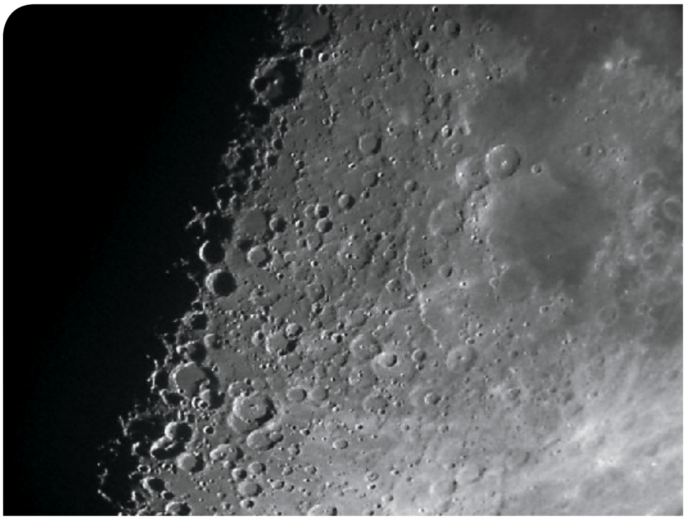
9 **Moretus Crater** sits in a heavily impacted region near the Moon's south pole. When the Sun angle is low here, you'll easily spot the central peak that rises 1.3 miles (2.1 km) above the surrounding floor. Moretus measures 71 miles (114 km) wide. Note that Cysatus Crater immediately to Moretus' north is deeper, so it still lies in shadow in this image. David Tyler



10 **Pitatus Crater,** which spans 60 miles (97 km), contains features strewn about its wide floor. A low central peak sits just to the northwest of the crater's center. Through an 8-inch telescope, look for the thin grooves called Rimae Pitatus on the western floor. More than 20 lettered (catalogued) craterlets surround Pitatus. Also be sure to observe the double-walled crater Hesiodus A directly to the west of Pitatus. Alan Friedman



11 **Plato Crater** lies at the Moon's top center for observers. Plato spans 63 miles (101 km) and has one of the darkest crater floors on the Moon. Polish astronomer Johannes Hevelius (1611–1687) called Plato the Greater Black Lake. One of the features to observe within this crater is its slumped inner wall, especially on the western (left) end. Even a small telescope at a magnification of about 100x will reveal the largest area, a triangular section that caved in millions of years ago. Alan Friedman



12 **The Lunar X,** also known as the Purbach or Werner Cross, appears at First Quarter near the terminator between the craters La Caille, Purbach, and Blanchinus. It sits 25° south of the Moon's equator and dead-center left to right. When the Lunar X is visible, sunrise is occurring over this region. The X remains visible for only 4 hours, so look carefully! Ohio amateur astronomer Dana Thompson captured this image of the Lunar X January 25, 2007, at 7:33 P.M. EST. Dana Thompson

crater they can see or how many small craters in a given area they can observe through a particular telescope.

If you take the second challenge, choose a mare or a crater with a large, flat bottom, and search for craterlets (small craters). For example, on the large crater Plato's (#11) floor are four craterlets, each about 1.25 miles (2 kilometers) across. You should be able to view those features through an 8-inch scope.

When observing larger craters, note whether you can see "rays" emanating from them. Those features formed when crushed rock sprayed out after an impact. Rays appear as radial streaks and can lie a great distance from the crater itself. For a good example, point your scope toward Copernicus (#4).

Dust off your scope

One of the best ways to familiarize yourself with the Moon is to undertake an observing project. Completing a project involves observing every item on its list, such as the 12 in this story. The Astronomical League hosts another such project, the Lunar Observing Club. Anyone can view the list, but to receive the certificate you must be a member of the league, either individually or through an astronomy club. For online details, see www.astroleague.org/al/obsclubs/lunar/lunar1.html.

A+ For the times when the Lunar X will be visible in 2010, go to www.Astronomy.com/toc.

Observing Basics

by Glenn Chaple

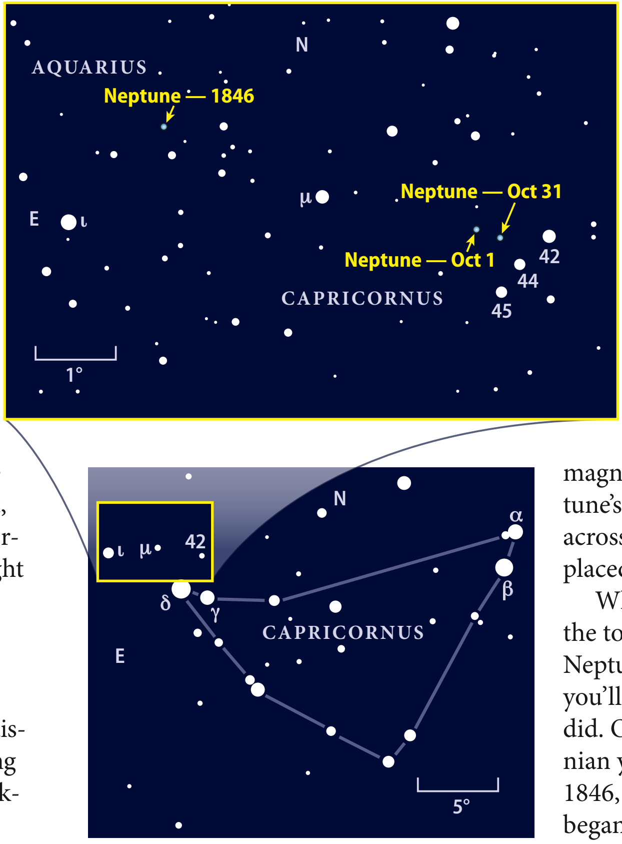
Predicting Neptune's existence

Discovering the eighth planet was a notable application of physics and mathematics.

Since January, this column has celebrated the triumphs of Galileo, who first turned a telescope on the heavens 4 centuries ago. Rather than look at another of his hits, let's examine one of Galileo's misses.

On several evenings between December 27, 1612, and January 28, 1613, Galileo observed and sketched Jupiter and its four bright moons. Each sketch included any background stars that were present. During this time, the space between two of these stars widened. Galileo noted the fact, but he failed to make follow-up observations. We can only guess what might have transpired had he done so — because the errant star was in reality the planet Neptune.

For the next 2 centuries, Neptune continued to elude astronomers. Its discovery came not with only the probing eye of the telescope, but with the workings of physics and mathematics. In 1781, the German-born British astronomer William Herschel discovered Uranus during a systematic telescopic survey of the heavens. For 40 years Uranus plodded along its orbital path. Then the planet mysteriously slowed down, which baffled astronomers. Had a passing comet struck Uranus? Not likely. Was a more distant and unseen body perturbing Uranus — obeying Newton's laws of gravity? Possibly.



Neptune lies in Capricornus this October, not far from the spot in Aquarius where Johann Galle first discovered the planet in 1846 based on Urbain Jean Jospeph Le Verrier's predictions.

Astronomy: Roen Kelly and Richard Talcott

Between 1843 and 1846, two mathematicians — John Couch Adams in England and Urbain Jean Joseph Le Verrier across the English Channel in France — labored independently to chart the location of the mystery object. Both calculated its position, but they each had difficulty convincing their countrymen to look for the new planet. Le Verrier finally found success when he sent his calculations to the German astronomer Johann Galle at Berlin Observatory. On September 23, 1846, the very first evening he looked, Galle saw a star where none was plotted in his atlas. High magnification betrayed a tiny disk. An eighth planet, eventually named Neptune, had joined the solar system. Today, although controversy still exists over the prediction, historians credit both Adams and Le Verrier with it.

By not following through with his observations, Galileo denied himself the honor of discovering Neptune. Had he done so, however, the scientific world would have lost both Adams' and Le Verrier's triumphant applications of physics and mathematics.

This month, Neptune is in the constellation Capricornus the Sea Goat, about 2° west and slightly south of the 5th-magnitude star Mu (μ) Capricorni and 1° east of 42 Capricorni. Through binoculars and low-power telescopes, it appears as an inconspicuous magnitude 7.9 star. A telescope magnifying 150x to 200x will reveal Neptune's tiny bluish disk. It's a mere 2.4" across — the equivalent of a golf ball placed 2.3 miles (3.7 kilometers) away.

Why put a planet you can barely see at the top of your must-see list? If you view Neptune before the summer of 2011, you'll have seen it in the same year Galle did. Of course, I'm referring to a Neptunian year, which equals 165 of ours. In 1846, when the current Neptunian year began, Galle spotted the planet with a simple 9-inch (23 centimeters) refractor. As the year draws to a close, we study Neptune with sophisticated computer-controlled reflecting telescopes dozens of times larger, as well as with the Hubble Space Telescope in Earth orbit. A lot can happen in a year!

It's interesting to note that Neptune and Jupiter are going through a triple conjunction as they did at the time of Galileo's observations. During its 2009 retrograde loop, Jupiter passed Neptune May 27 and July 10. A third encounter occurs December 21 when Jupiter drifts ½° south of Neptune. Galileo missed his opportunity to discover Neptune. Don't miss yours!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: Jupiter and the Medicean stars. Clear skies!

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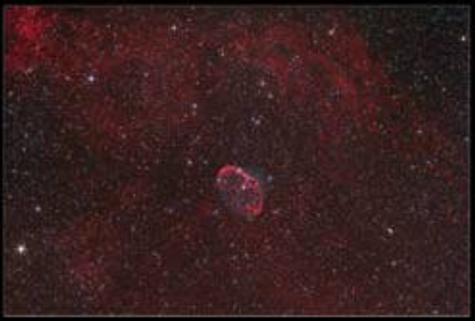

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Secret Sky

by Stephen James O'Meara

The fun-house porch

This asterism holds the Garnet Star, an open star cluster, and an emission nebula.

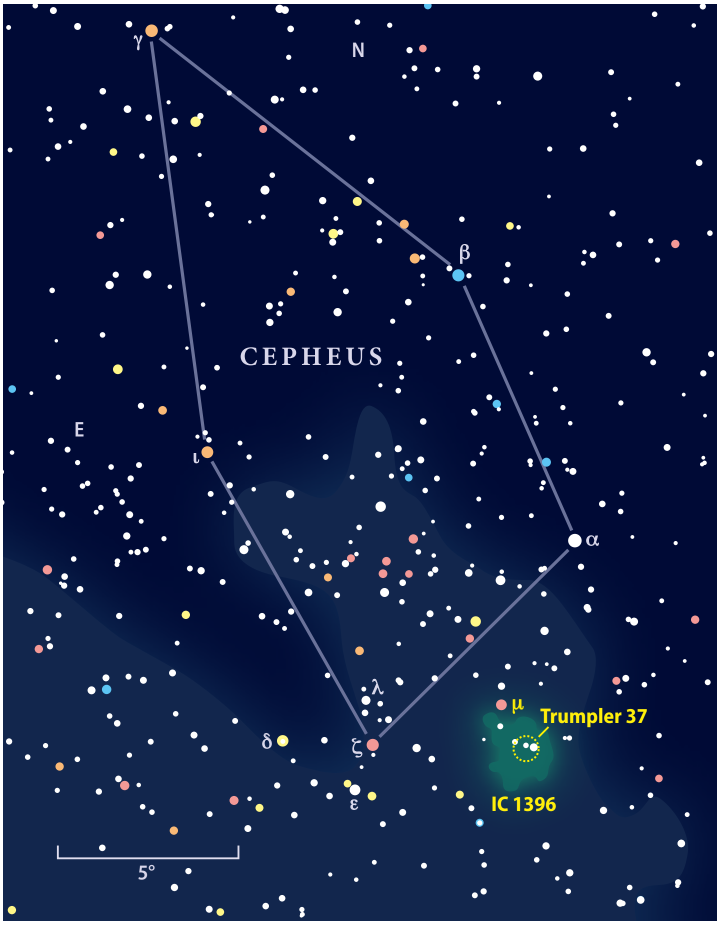
Cepheus the King stands high in the northern night sky shortly after sunset. By mid-October, at 9 P.M., its famous house-shaped asterism appears upside down directly above the North Celestial Pole. The House and its greater surroundings are home to several celestial delights. But I'm going to bring you only to what I call the House's "front porch" — the region south of Zeta (ζ) and Alpha (α) Cephei. Here we'll find a few of the constellation's most exotic wonders in an area of sky less than 3° across.

Scarlet star

What could be better than to start with Mu (μ) Cephei, the reddest star visible to the unaided eye? You'll find this gem about 4¾° southeast of 2nd-magnitude Alpha or 3½° west (and ever-so-slightly north) of 3rd-magnitude Zeta.

Mu, popularly known as Herschel's Garnet Star, shines with the creepy color of blood in small apertures and appears to stain the carpet of the Cepheus region of the Milky Way. In larger telescopes, or at high magnifications, its color can appear more pumpkin or squash. The color you see may also depend on the star's magnitude. Mu is a slow variable star whose brightness changes from magnitude 3.4 to 5.1 in a semiregular period of 800 to 1,000 days. Generally, the fainter Mu is, the redder it appears. Of course, color perception is highly subjective; everyone sees color differently. Atmospheric and physiological effects can further affect what we see.

But Mu is much more than a colorful curiosity. It is one of the largest stars visible to the unaided eye. This luminous red supergiant measures some 1.4 billion miles (2.3 billion kilometers) across at its equator. If it were to replace our Sun, its atmosphere would reach halfway between Jupiter and Saturn. The life expectancy of such an enormous star is only around a few million years. So keep watch because Mu Cephei could possibly become our next supernova!



Find your way to the King's House; then focus on the "front porch." Here you'll see the Garnet Star, multiple-star systems, and more. *Astronomy*: Roen Kelly

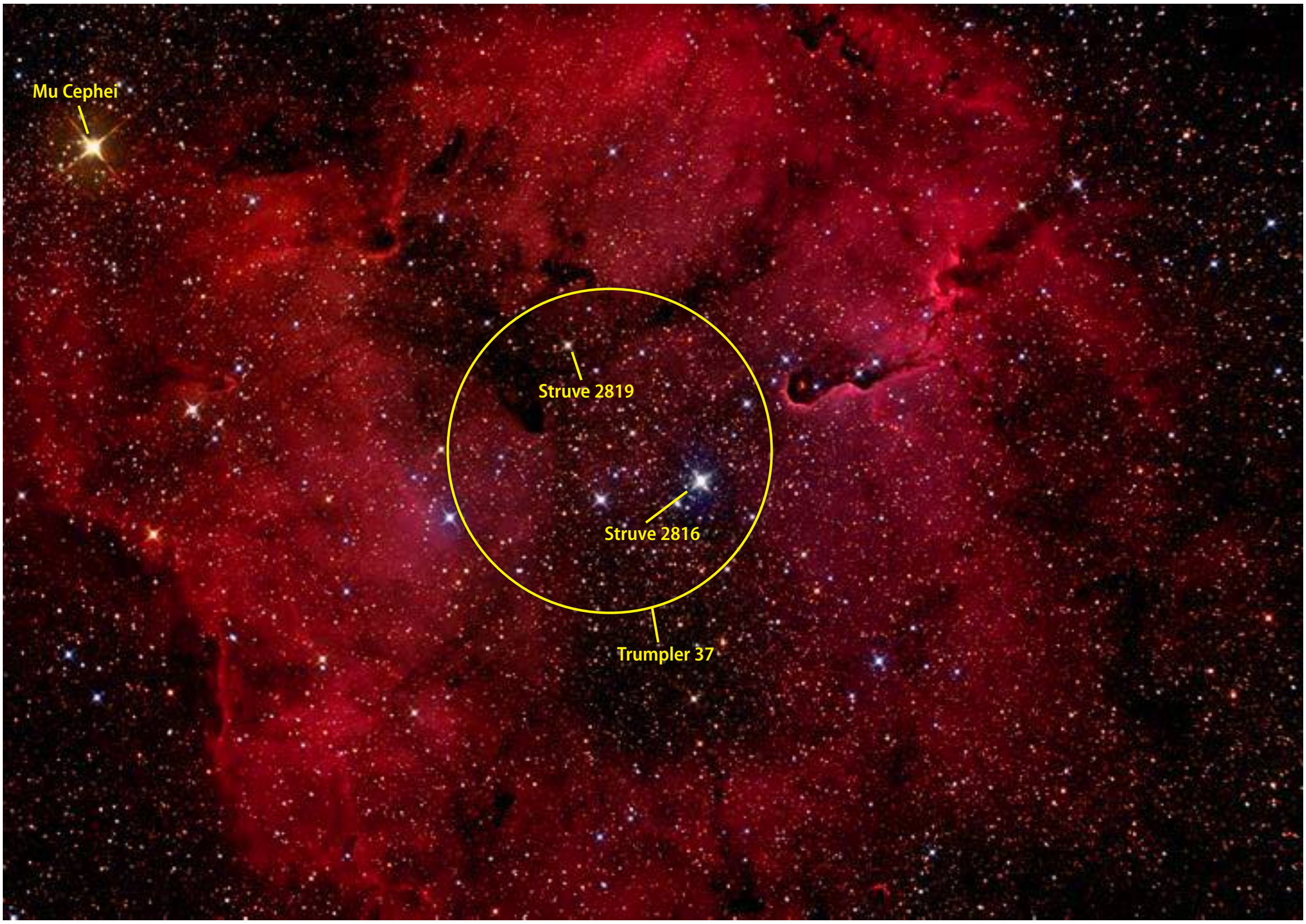
Colorful couples

Less than 1½° south of Mu is another large Cepheus wonder: open star cluster Trumpler 37. Through a telescope at low power, this 3.5-magnitude object is a rich cluster of stars with an X-shaped core and looping outer arms — like flower petals. We see its members against the backdrop of the Milky Way, so the field is a visual feast.

A 5.6-magnitude star lies close to the cluster's core. But look carefully at it through your telescope because here is the colorful triple system Struve 2816 — one of the prettiest multiple-star systems in the heavens.

In his *Cycle of Celestial Objects*, Admiral William Henry Smyth (1788–1865) writes of it: "Through all anomalies, here are palpable gleams of a force which penetrates through creation; and wondrous is the inference! Those mighty orbs move through a space in a curve which it bewilders the mind to figure, obediently to a mysterious impulse which binds them in affinity with some vast central phenomenon."

Under steady atmospheric seeing at 72x and greater in my 5-inch f/5 refractor, the primary burns with a warm-topaz light. Its two nearly 8th-magnitude attendants — one 12" away, the other 20" (almost in a straight line with the primary) — share pale-aqua hues. James Mullaney, co-author of *The Cambridge Double Star Atlas* with Wil Tirion, says that through 5-inch and larger telescopes,



Herschel's Garnet Star (Mu [μ] Cephei) shines at the northeast corner of the nebula IC 1396, but the two objects are not related. Be sure to also check out the open star cluster Trumpler 37 and both Struve multiple-star systems. Bob Fera

the primary appears bluish-white, while its "nearly matched companions are blue-green and purple or violet."

Move your scope just 15' northeast, and you'll see double star Struve 2819. In my scope at 72x, both multiple-star systems fit comfortably in the same field of view! Struve 2819 is an uneven pair that consists of an eggshell-white primary (magnitude 7.5) and a white secondary (magnitude 8.5) 12.4" to the east-northeast. Mullaney says the primary is "pale yellowish" and the dimmer companion looks "white."

Mystery mist

To the unaided eyes, Trumpler 37 appears as a breath of light against the soft glow of the Cepheus Milky Way. You may have difficulty detecting the cluster, which requires a dark and crystal-clear sky. Even then, you'll need to ponder the view carefully. The cluster covers an area of 1½° (the apparent diameter of 3 Full Moons), so the low-contrast glow makes a fun naked-eye challenge.

Curiously, the visual haze you see may not be just from the cluster. Some of it could be from IC 1396 — the larger (nearly 3° by 2°) swath of emission nebulosity surrounding Trumpler 37. I have suspected seeing IC 1396 with my unaided eyes and binoculars under extremely dark Hawaiian skies and am wondering if you can do the same, especially with the aid of a deep-sky or ultra-high-contrast filter.

IC 1396 is one of the largest emission nebula complexes in the sky. Its northern limit extends to Mu Cephei, which makes the nebula and star appear intimately related. Actually, they're not. Mu Cephei lies at a distance of some 2,700 light-years from Earth, but the IC 1396 and Trumpler 37 complex is roughly 100 light-years closer.

The nebula's shell-like glow may appear more definite in a rich-field telescope at low power. Mullaney, for instance, says that he spied IC 1396 using a 3-inch f/5 refractor at 30x. Seeing it, he says, demanded a moonless night of better-than-average transparency: "Slow sweeping back and forth using averted vision definitely showed the nebulosity in the 1½° field of view."

I've seen it in a 4-inch refractor at 23x. But others under dark skies using a variety of instruments have not had success, even with filters. So the visual sightings remain controversial.

By the way, if you have a rich-field telescope and can see IC 1396, I'd especially like to know if you can pick out any of the nebula's dusty cobwebs (the dark nebulae) that cover its face. The darkest and most prominent patch is Barnard 161. It's a small dark patch about 20' north of Struve 2819. It measures some 20' in extent, but the darkest part is only 3' across. Good luck. Send your reports to someara@interpac.net.

Telescope**insider**

by Michael E. Bakich

David **Nagler**

President, Tele Vue Optics

Being the son of Al Nagler, you'd expect that David Nagler learned something about optics at an early age. Photography captured his youthful imagination, so learning about focal lengths, focal ratios, and image formation from his dad gave Nagler the tools to capture an image as he saw it. Born in New York City, Nagler started checking projection TV lenses at age 14 while Tele Vue still operated from his parents' house.

Nagler graduated from Syracuse University with a degree in Television, Radio, and Film Production. His senior thesis, a tutorial video for Tele Vue dealers called "Simply Speaking Telescopes," prophetically pointed toward his future.

After graduating, he worked in the freelance film world for a couple of years, but the lack of a steady paycheck disillusioned him. It was 1988, and the time was right for Tele Vue to have a full-time operations manager. Nagler suggested to his father that he knew just the right person.

Nagler, president of the company since 2004, likes to work behind the scenes on product development, manufacturing, and advertising. He also is proud of the fact that Tele Vue still feels like a family company. People are cross-trained, and, as he says, "In this economy it's especially nice to tell our people they're needed."

Image courtesy Tele Vue Optics

David Nagler poses with two of his favorite Tele Vue scopes: the TV-127is (left) and the TV-101is apochromatic refractors.

Tell me about your most popular products.

On the telescope side, it's a toss-up between the TV-85 and NP-101. Both offer good aperture and portability. People like to make "travel kits" with them. Our Ethos eyepiece series also has been a tremendous success. We couldn't be happier with the way it's been received by amateur astronomers.

Tell me something cool about Tele Vue.

My father [Tele Vue's founder, Al Nagler] hasn't worked here full time throughout our history. In the beginning, my mother [Judi] ran the company.

A lot of our obsessive quality control was a function of people who worked at Tele Vue in the early years. One was Joe Folmer, our first telescope production manager, who worked here from 1984 until he retired in 2001. I make sure everyone here understands the lessons of the past.

How has Tele Vue changed through the years?

Tele Vue has certainly grown up, but our mission has not changed. Our drive to create unique products to fill needs is the same now as it was on day one. Physically, we've gone from a kitchen table to a small old factory building, to a large purpose-built facility, but what we do really hasn't changed.

> *"We've gone from a kitchen table to a small old factory building, to a large purpose-built facility, but **what we do really hasn't changed**."*

Tony Hallas

Do you enjoy observing?

I'm very much a visual observer who likes to frame "themes" — whether they are astronomical or terrestrial — to what I think is aesthetically pleasing. Getting out under dark skies at big star parties is important to me. I can do a year's worth of observing in one week, and it inspires me.

Can you share anything about upcoming products?

We've been expanding the Ethos line with logical steps in focal lengths. It's a difficult process because we can't just scale the designs up or down. If we did that, our long-focal-length eyepieces would be enormous and short-focal-length eyepieces would have tiny eye relief. So, each design is unique. Our newest model, the 10mm Ethos, may see a sibling soon.

Where, in your opinion, is the hobby headed?

With our customers in mind, I'd say the hobby is headed toward dark skies. Portable equipment allows amateur astronomers to get to optimal observing conditions. Unfortunately, light pollution has taken away a lot of the "awe" of the sky from peoples' daily lives. Anything we can do to restore the darkness of the sky so people can go outside their home and say "Wow!" is going to be good for the hobby. ◐

New Products

4-inch refractor

Vixen Optics
San Clemente, California

Vixen Optics' AX103S f/8 refracting telescope features a 4-inch (103mm), three-element achromatic objective lens. The scope also incorporates Vixen's rear Field Corrector Lens. All lenses have multi-coating. The built-in Dual Speed Focuser enables coarse and fine focus adjustments. The scope measures 32.4 inches (825 millimeters) long.

Price: $2,999
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[w] www.vixenoptics.com

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14mm 82° eyepiece

Explore Scientific
Laguna Hills, California

Explore Scientific's 1¼" 14mm 82° Series Eyepiece combines low-dispersion and high-refractive-index optical glass. Explore Scientific multicoated all optical surfaces, and the eyepiece's internal surfaces are flat black. Eye relief is 15mm. The eyepiece weighs 11.8 ounces (335 grams).

Price: $149
[t] 888.599.7597
[w] www.explorescientific.com

Camera mount

Orion Telescopes and Binoculars
Watsonville, California

Orion's SteadyPix Deluxe securely couples any digital camera or DSLR to a telescope eyepiece for afocal photography. The mount offers horizontal, vertical, and depth adjustments and fits all 1¼" and most 2" eyepieces (up to 61mm in diameter).

Price: $44.95
[t] 800.447.1001
[w] www.oriontelescopes.com

82° field eyepiece

Orion Telescopes and Binoculars
Watsonville, California

Orion's 4mm MegaView Ultra-Wide Eyepiece boasts a 17mm ocular lens diameter, 12mm of eye relief, and multicoating. The apparent field of view measures 82°. The eyepiece weighs just 7.2 ounces (204g) for easy transport.

Price: $197.95
[t] 800.447.1001
[w] www.oriontelescopes.com

Vue 10mm Ethos

10mm Ethos eyepiece

Tele Vue Optics
Chester, New York

Tele Vue Optics' 10mm Ethos eyepiece features a 100° apparent field of view and 15mm of eye relief. It fits either 2" or 1¼" focusers. The 10mm Ethos weighs 17.6 ounces (499g).

Price: $558
[t] 845.469.4551
[w] www.televue.com

Motofocus for Synta refractors

JMI Telescopes
Lakewood, Colorado

JMI Telescopes' Motofocus for William Optics Replacement Focuser for Synta refractors is small and lightweight. The unit installs quickly and features a steel bracket. This focuser also fits William Optics' Megrez 90 apochromatic refractor.

Price: $160
[t] 800.247.0304
[w] www.jmitelescopes.com

Field flattener for APO refractors

APM America
Hawthorne, New Jersey

APM announces the arrival of TS Optics' 2.5" Field Flattener for apochromatic refractors. The zero-power flattener has an open aperture of 62mm. It works in conjunction with refractors that have focal ratios from f/5 to f/9. The distance between the flattener and the CCD sensor is 3.6 inches (91.5mm).

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Red observing light

Aurora Astro Products
Everett, Washington

Aurora Astro Products' Astronomers Observing Lamp offers two illumination levels. A special diffuser eliminates "hot spots." The light has a weighted base, so it can sit upright on a table. Power comes from three D batteries (not included).

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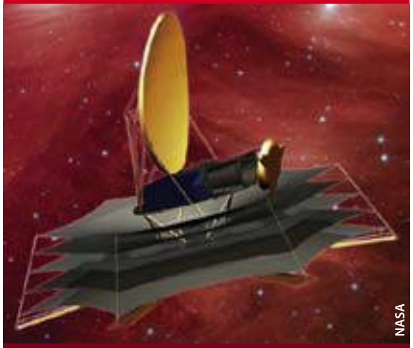

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All things high, low, weird, and wonderful in astronomy and space science. **by Daniel Pendick**

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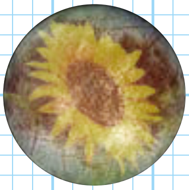
Mannequin macabre

The European Space Agency's "Matroshka" limbless torso measures radiation exposure to the body on the space station — and gives astronauts blood-curdling nightmares?

Anybody home?

The SETI@home project celebrates 10 years of searching radio data for signs of extraterrestrial intelligence using volunteer computer time. So far, no phone calls from E.T.

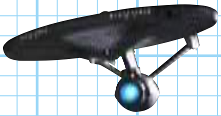


Life light

Futurist Freeman Dyson says life on Europa could take the form of space-hardened sunflowers harvesting solar rays from within cracks in the moon's icy crust.

Spitzer speaks

PlanetQuest web site posts a charming mock interview with NASA's Spitzer Space Telescope. Says Spitzer, "You think my pictures are pretty? Thank you!"

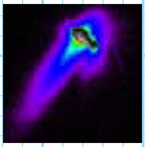


Cool!

Baylor University physicists Gerald Cleaver and Richard Obousy say a new wrinkle on super-string theory makes faster-than-light travel theoretically possible.

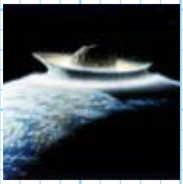
Bummer!

Calculations by University of Utah physicists Joseph Spencer and James Wheeler show that faster-than-light "tachyon" particles are fundamentally impossible.



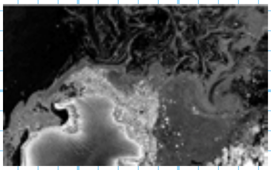
Stealth attack

Thousands of ice-poor "dark comets" may be prowling the solar system looking for an unsuspecting planet to crash into unannounced.



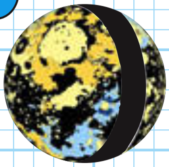
Life's a blast

A new computer model reveals that the sterilizing rain of asteroids 4 billion years ago may have also created a place for nascent Earth life to hide — deep impact cracks.



See it as it happens

EnviroSat's "Webcam from Space" lets you watch the scary effects of global warming on Antarctica's unstable Wilkins Ice Shelf.



Brother Mars

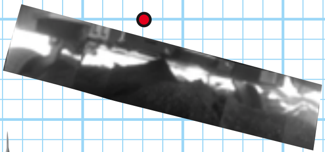
MESSENGER spacecraft scientist Brett Denevi says that volcanism on Mercury was widespread and formed much of its crust in repeated eruptions — just like on Mars.

Space cadets

Four teenagers at the IES La Bisbal school in Catalonia, Spain, capture this gorgeous image of Earth using a $90 Nikon digital camera lofted on a high-altitude sounding balloon.

Killing time

The Spirit Mars rover, trapped in soft soil, photographs a new view ... of her underbelly. Scientists are planning her escape.



Stars of steel

Indiana University physicist Charles Horowitz calculates that the surface crust of a neutron star may be 10 billion times stronger than steel.

Magic trick

Earth passed through Saturn's ring plane September 4. Hope you enjoyed the view, because it won't happen again until 2025.

Spin control

Radio astronomers may have figured out what causes pulsar J1023 to rotate 592 times per second. Gas dumped on the superdense stellar cinder from a nearby companion star spins it like a top.

NASA: the next generation?

By 2014, nearly half of NASA's civil-service employees will be ages 50–59. "NASA must reverse course in President Obama's first term or key intellectual capabilities will be lost and not replaced." — Gregory J. Junemann, president International Federation of Professional & Technical Engineers, testimony to Congress, April 22, 2009

High-altitude hijinks

In one of 16 challenges suggested by the Japanese public, space station astronaut Koichi Wakata demonstrates how to administer eye drops in zero gravity.

PHOTOGRAPHS: ESA (Mannequin); Courtesy of the NAIC-Arecibo Observatory, a facility of the NSF (SETI@home project); *Astronomy*: Chuck Braasch (Enterprise); Don Davis/NASA (Life's a blast); NASA/JPL-Caltech (Spitzer); ©2009 Jupiterimages Corporation, NASA/JPL/DLR (Sunflower and Europa); NASA/JPL-Caltech (comet); ESA (Webcam from Space); NASA/JPL/USGS (Spirit Mars rover); ©2009 Jupiterimages Corporation (steel); JAXA (eye drops); NASA Glenn Research Center (NASA-GRC) (Man with rocket); NASA/JHUAPL/ASU/CIW (Brother Mars); Meteotek/IES La Bisbal School (Earth); Erich Karkoschka (University of Arizona Lunar & Planetary Lab)/NASA/ESA (Saturn); ©2009 Jupiterimages Corporation (Spin control)

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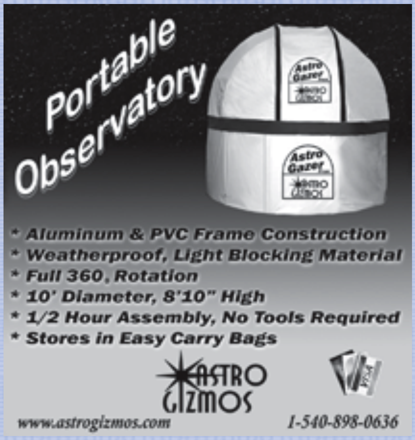
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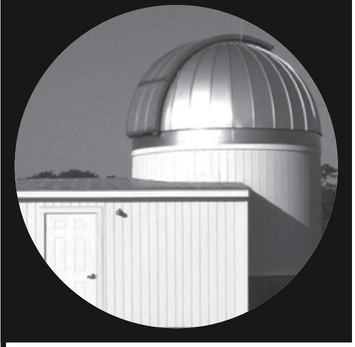

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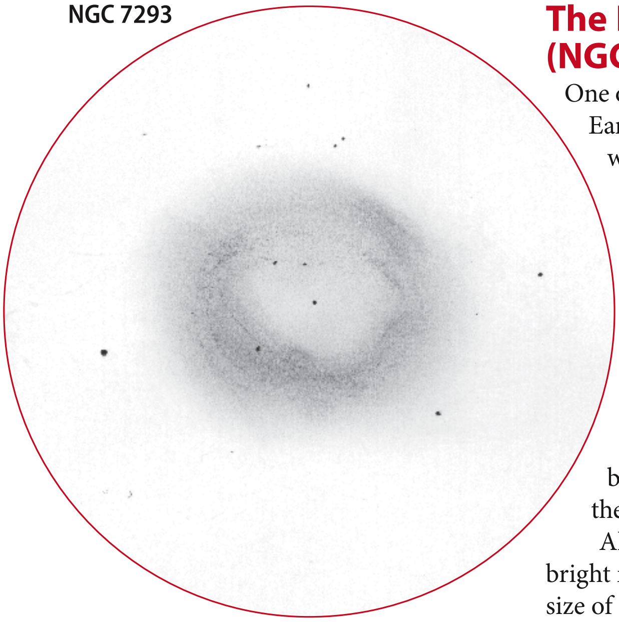
The Helix Nebula and Owl Cluster

Astronomy's editor sketches two of his favorite objects.

by David J. Eicher

NGC 7293



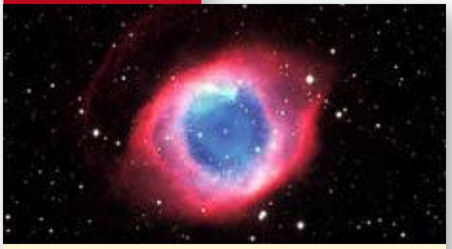
The Helix Nebula sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

The Helix Nebula (NGC 7293)

One of the closest planetary nebulae to Earth, the Helix Nebula foreshadows what will happen to the Sun at the end of its life. As a middleweight Sun-like star sheds mass in a planetary nebula phase, it blows off concentric shells of gas that glow from afar in colorful, varied shapes. The Helix gets its name from its resemblance to a helical coil, like DNA. The shell appears to have rings of bright nebulosity because they are the densest parts of the gas from our viewpoint.

Although the Helix has a relatively bright magnitude (around 7), its huge size of 19' for the inner disk we see — and even larger for the outer, fainter gas — means it has a low surface brightness.

NGC 7293

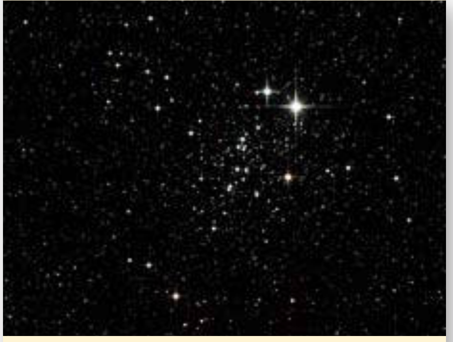


James R. Foster

Designation: NGC 7293
Position: 22h30m, −20°50' (2000.0)
Constellation: Aquarius
Magnitude of central star: 13.5
Size: 25'
Distance: 700 light-years

Observe the Helix on a moonless night. A 6-inch telescope will show a faint glow without structure. A large scope, like the one I sketched the Helix with (a 17.5-incher), brings out some mottled areas of the ring shape and the dim central star.

NGC 457



Anthony Ayiomamitis

Designation: NGC 457
Position: 1h20m, 58°17' (2000.0)
Constellation: Cassiopeia
Magnitude: 6.4
Magnitude of brightest star: 8.7
Size: 13'
Distance: 7,900 light-years

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 33 years.*

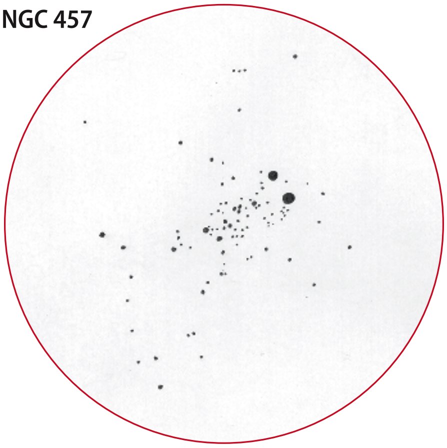
The Owl Cluster (NGC 457)

When I was a teenager observing from a field in southern Ohio, I took a special liking to one little bright open cluster in Cassiopeia, NGC 457. I observed it night after night, and during one such session, the cluster suddenly suggested a nickname. Two bright stars and a "body" of fainter suns, plus arcing "wings" spreading from the body, suggested an owl shape, so I named it the Owl Cluster in the pages of *Deep Sky Monthly*. A telescopic view will show you what I mean.

The cluster lies 7,900 light-years away and holds 80 stars in a 13' diameter, about one-third the size of the Full Moon. What makes the cluster alluring is the richness of the Milky Way field it inhabits. The magnitude 5.0 star Phi (ϕ) Cassiopeiae is the cluster's brightest star and a rare class F that astronomers classify as a yellow hypergiant. It serves as one of the owl's "eyes," although in reality it lies in the foreground, less than a third of the distance to the cluster. Another bright star creates a slightly dimmer "eye"— nearby magnitude 7.0 SAO22187.

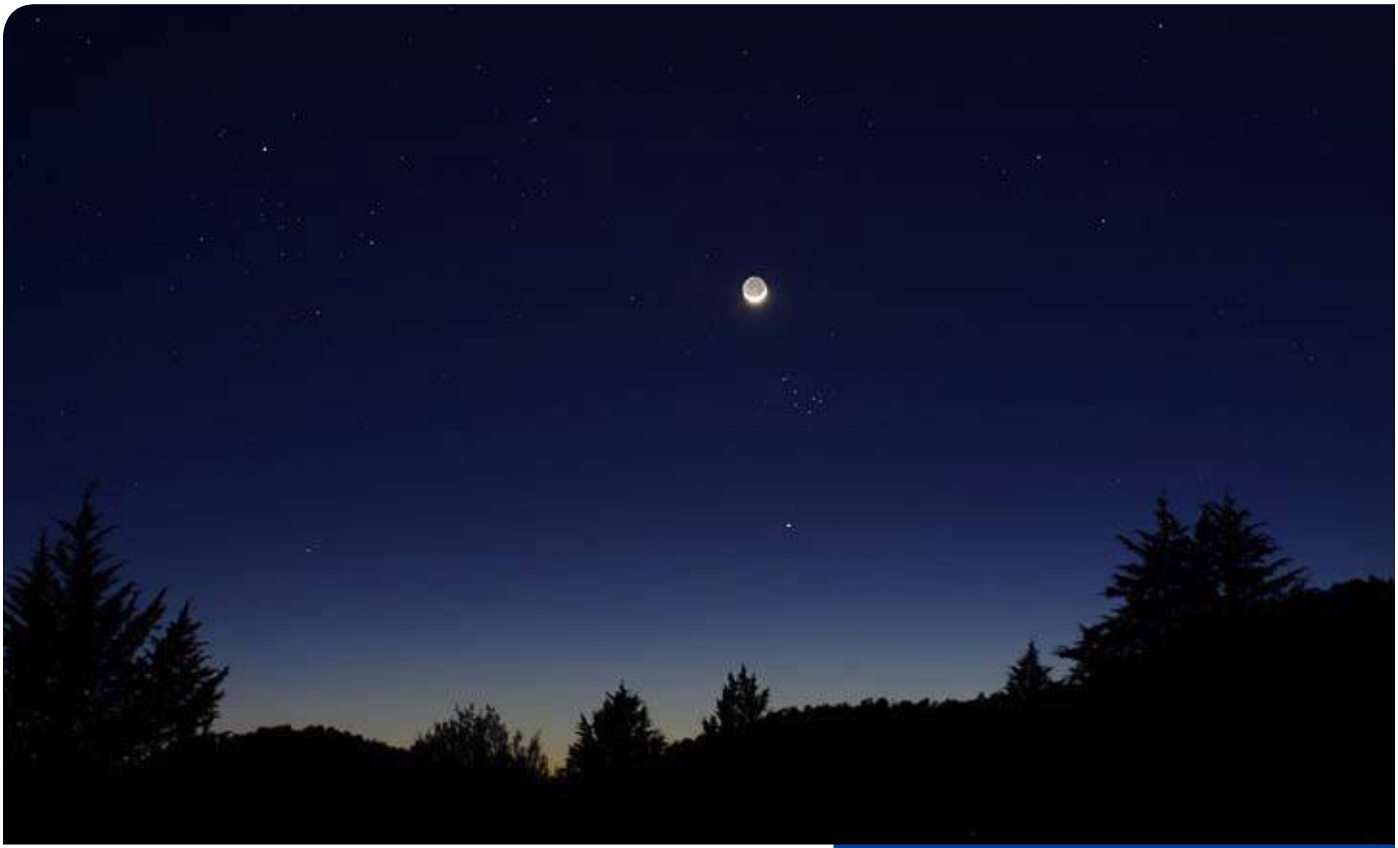
I always found that an 8-inch scope on a dark night provided a satisfying view of the Owl even at low powers. I know you'll return to the Owl again and again.

NGC 457



The Owl Cluster sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

reader gallery

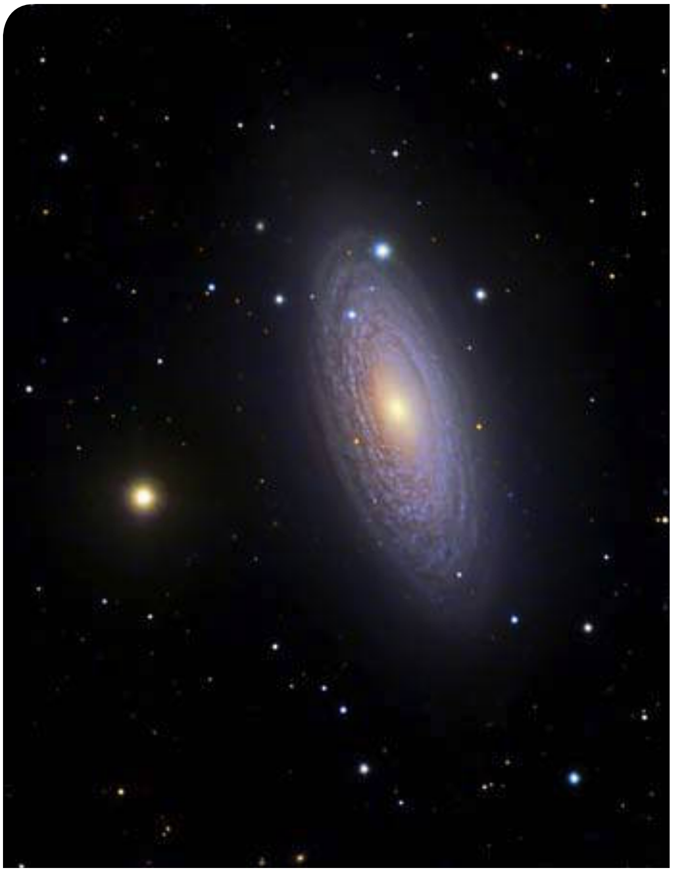


The Moon, the Pleiades, and Mercury (Canon 10D digital SLR, Canon 17-40mm lens set at 40mm, ISO 200, 30-second exposure driven on a "barn door" mount, taken April 26, 2009, at 8:17 P.M. MST) • Chris Schur, Payson, Arizona

The Salt and Pepper Cluster (M37) in Auriga is that constellation's richest cluster. M37 contains nearly 2,000 stars and lies some 4,000 light-years away. (5.4-inch TEC 140 apochromatic refractor at f/7, SBIG ST-10XME CCD camera, RGB image with exposures of 30, 30, and 45 minutes, respectively) • Ruben Kier, Orange, Connecticut

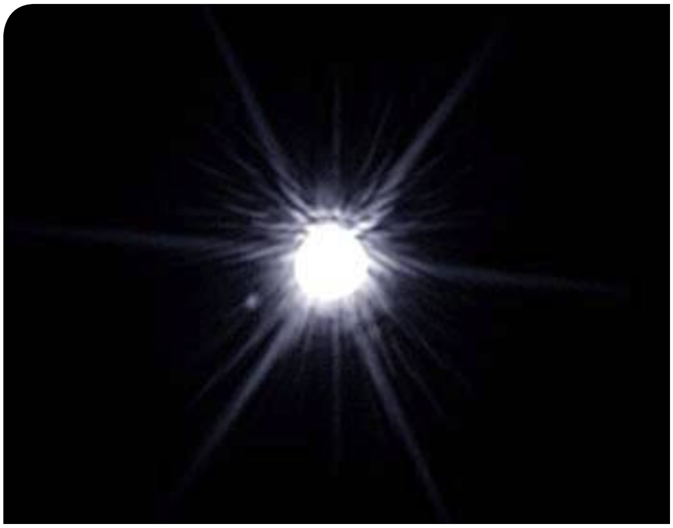
A great evening get-together

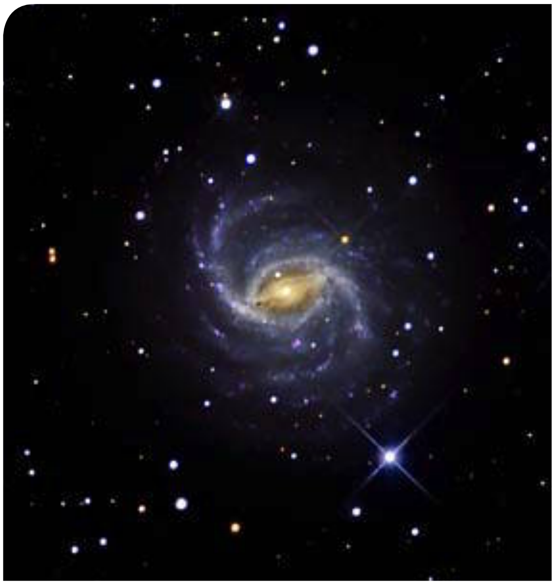
On April 26, 2009, astroimager Chris Schur viewed a spectacular gathering. Low in the west, he saw the thin young Moon, complete with earthshine. It began a 5°-long line with two other objects. Just underneath the Moon was the Pleiades star cluster (M45). Farther down, the planet Mercury sat just under the Pleiades. Schur's image is a 30-second exposure that captures the last deep cobalt-blue of evening twilight. He took this shot near his house in a large open field with Juniper pine trees framing the event.



< **Spiral galaxy** NGC 2841 in Ursa Major features tightly wound spiral arms. The galaxy shines at magnitude 9.3. Compare its brightness to that of the magnitude 8.5 yellow giant star just to its left. (12-inch Meade LX200R telescope at f/7, SBIG ST-10XME CCD camera, LRGB image with exposures of 165, 45, 35, and 40 minutes, respectively) • Ruben Kier, Orange, Connecticut

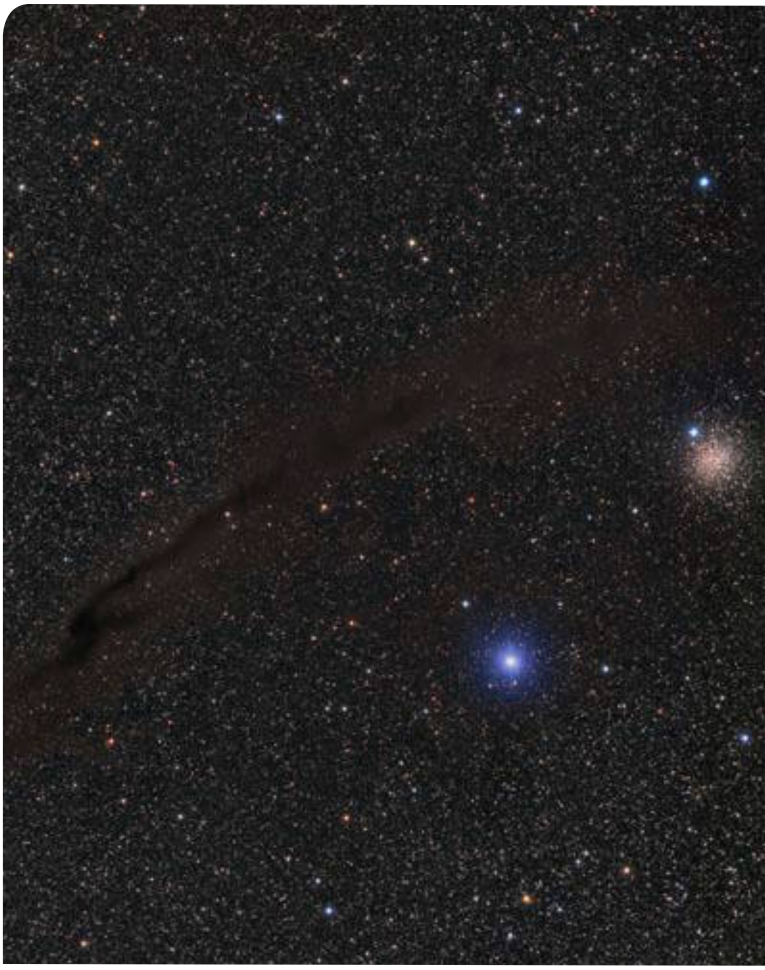
V **Sirius** (Alpha [α] Canis Majoris) is the sky's brightest nighttime star. Its companion, Sirius B (lower left), was the first white dwarf discovered. American telescope-maker Alvan Graham Clark found it in 1862 while testing a lens. (10-inch Takahashi Mewlon 250 Dall-Kirkham reflector at f/50, Lumenera SKYnyx 2.0M CCD camera, 1,800 frames, stacked) • Damian Peach, Loudwater, England

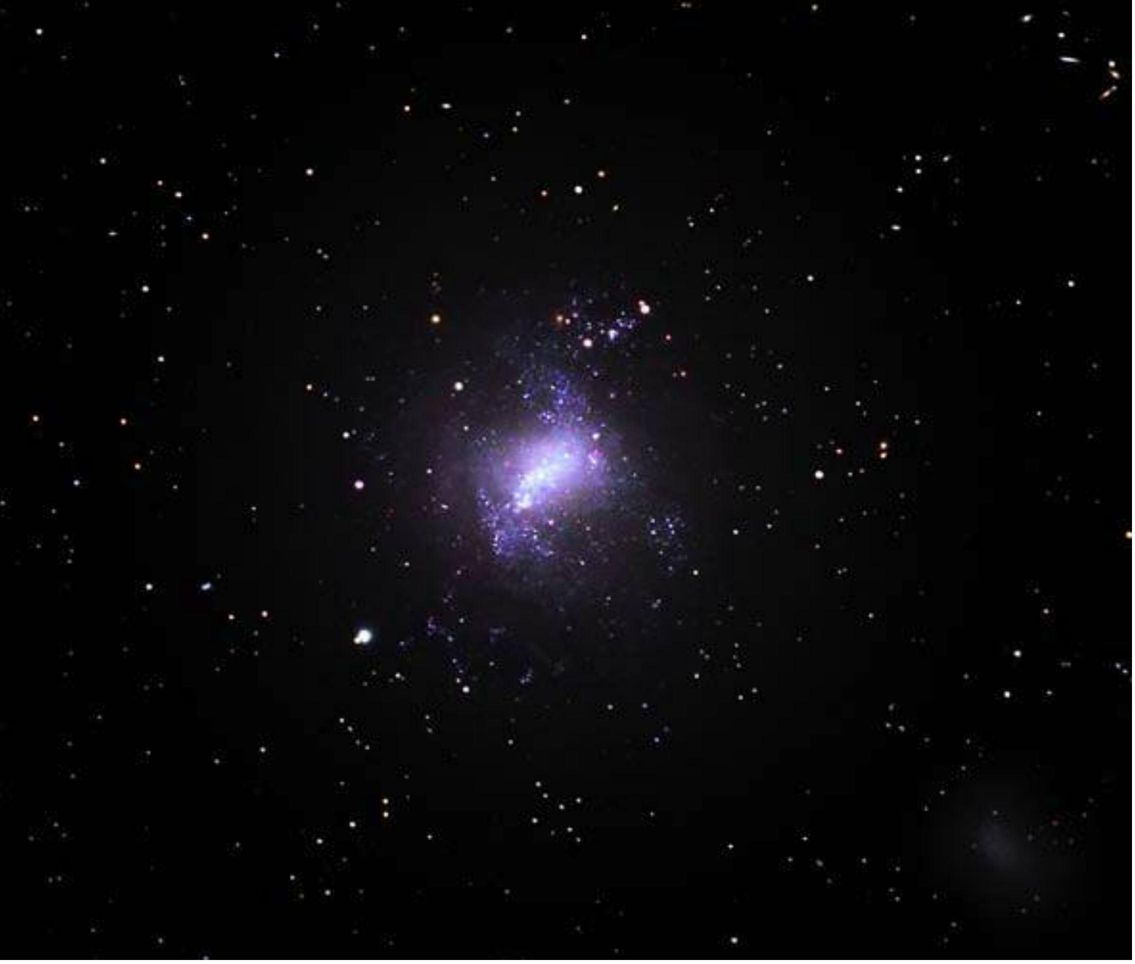




^ **Spiral galaxy NGC 5921** in Serpens shines at magnitude 10.7 and displays multiple spiral arms. It lies approximately 65 million light-years away. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-6303M CCD camera, LRGB image with all exposures 4 hours long) • Keith B. Quattrocchi, Clovis, California

> **The Dark Doodad** in the southern constellation Musca the Fly also has the designation HMSTG 436. The star to its right is magnitude 3.8 Gamma (γ) Muscae, and the globular cluster is magnitude 7.2 NGC 4372. (6.2-inch Astro-Physics 155EDF apochromatic refractor at f/5.4, FLI Proline KAF-16803 CCD camera, LRGB image with exposures of 160, 100, 60, and 100 minutes, respectively) • Thomas V. Davis, Inkom, Idaho





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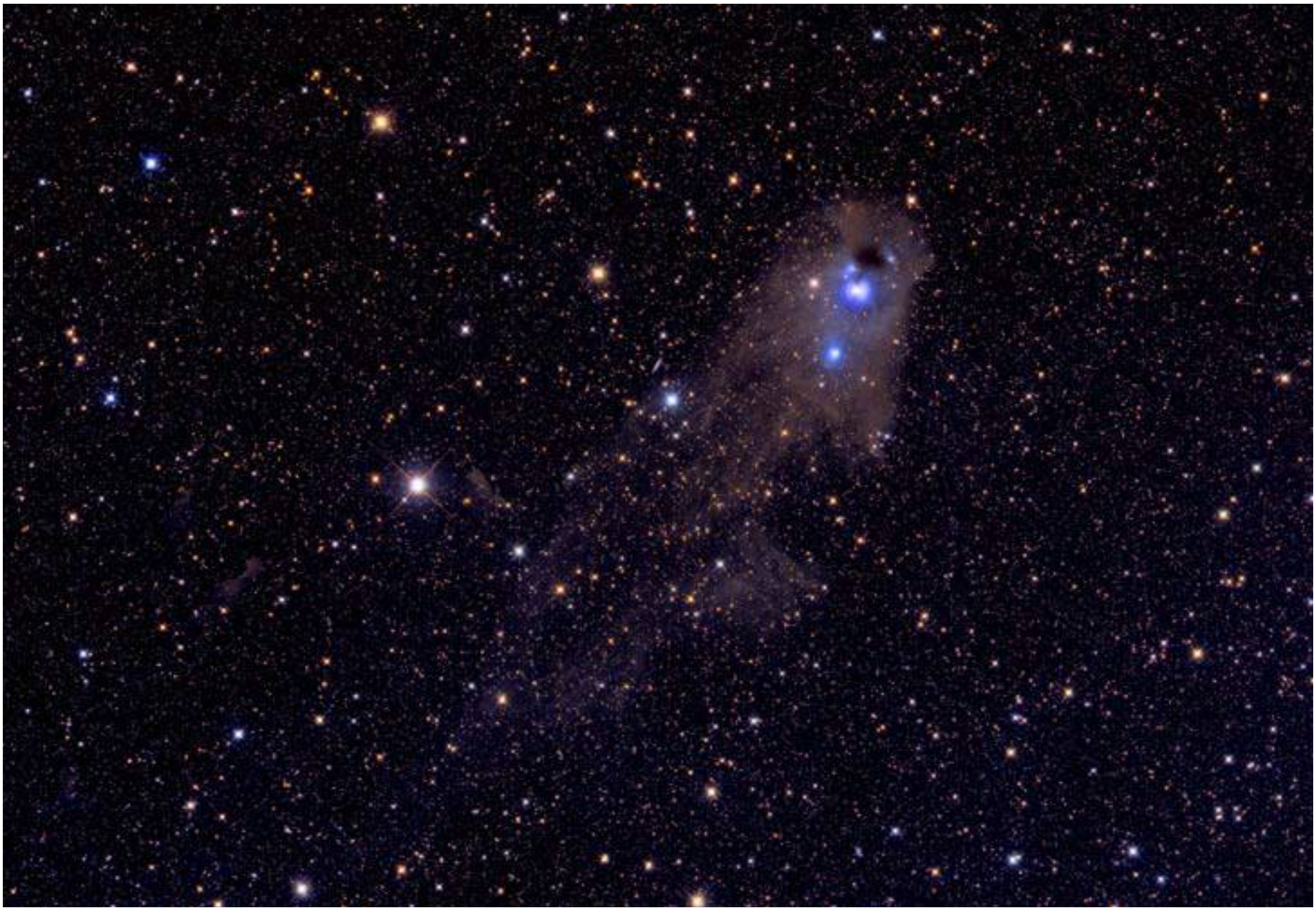
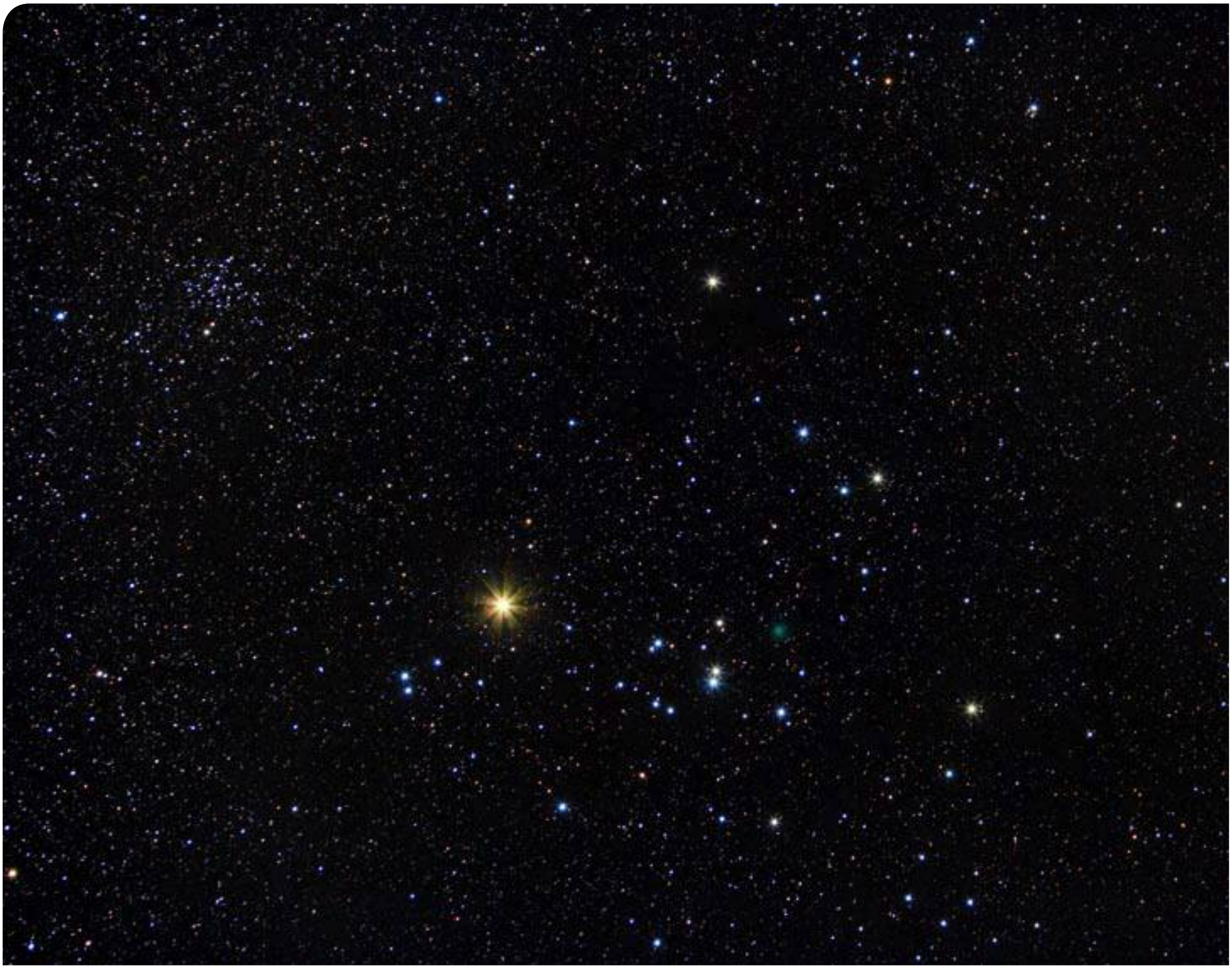
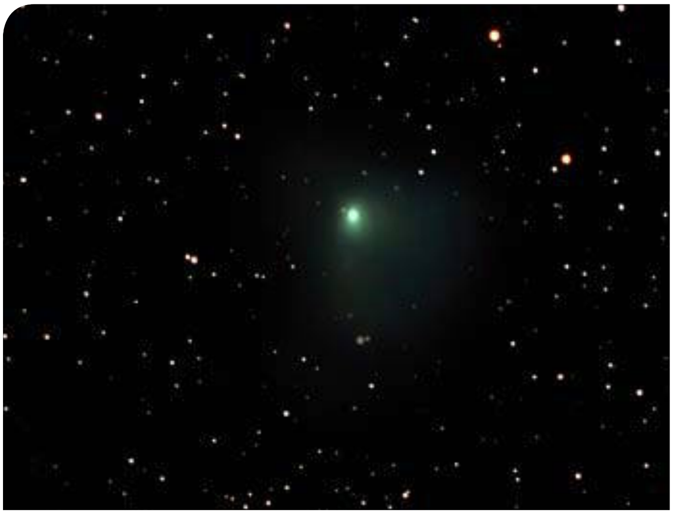
< Irregular galaxy NGC 4214 in Canes Venatici shines at magnitude 9.6. The small galaxy to the lower right is UGCA 276. It glows faintly at magnitude 18.5. (9-inch TMB apochromatic refractor at f/9, Starlight Xpress SXV H16 CCD camera, LRGB image with exposures of 120, 50, 50, and 50 minutes, respectively) • Dietmar Hager, St. Johann am Wimburg, Austria

V Reflection nebula NGC 5367 lies 4° south-southwest of magnitude 2.1 Theta (θ) Centauri. The nebula's dust and gas dims light from the stars in the sparse cluster by about a magnitude. (8-inch ASA astrograph at f/3.8, FLI 6303E CCD camera, LRGB image with exposures of 70, 20, 20, and 30 minutes, respectively) • Gerald Rhemann and Michael Jäger, Farm Tivoli, Namibia

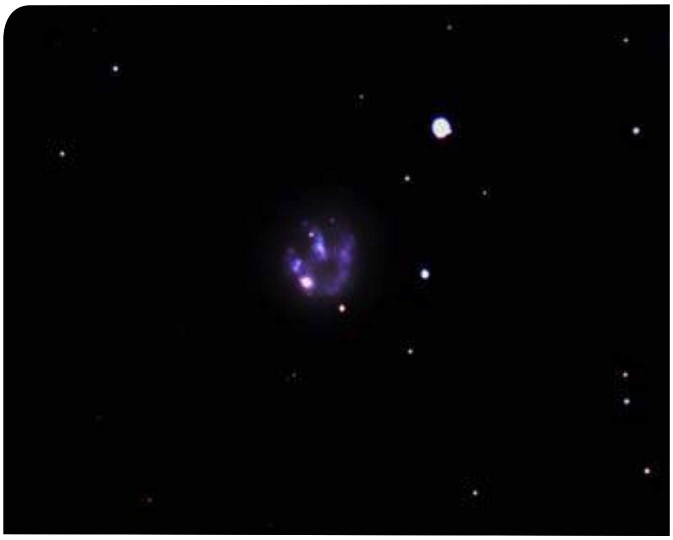




Comet 144P/Kushida appeared in front of the brilliant stars of the Hyades cluster in Taurus last February. (Canon XTi digital SLR, Canon 100-400L lens set at 100mm and f/5.6, ISO 800, twelve 5-minute exposures, taken February 1, 2009, at 9:52 P.M. MST) • Chris Schur, Payson, Arizona



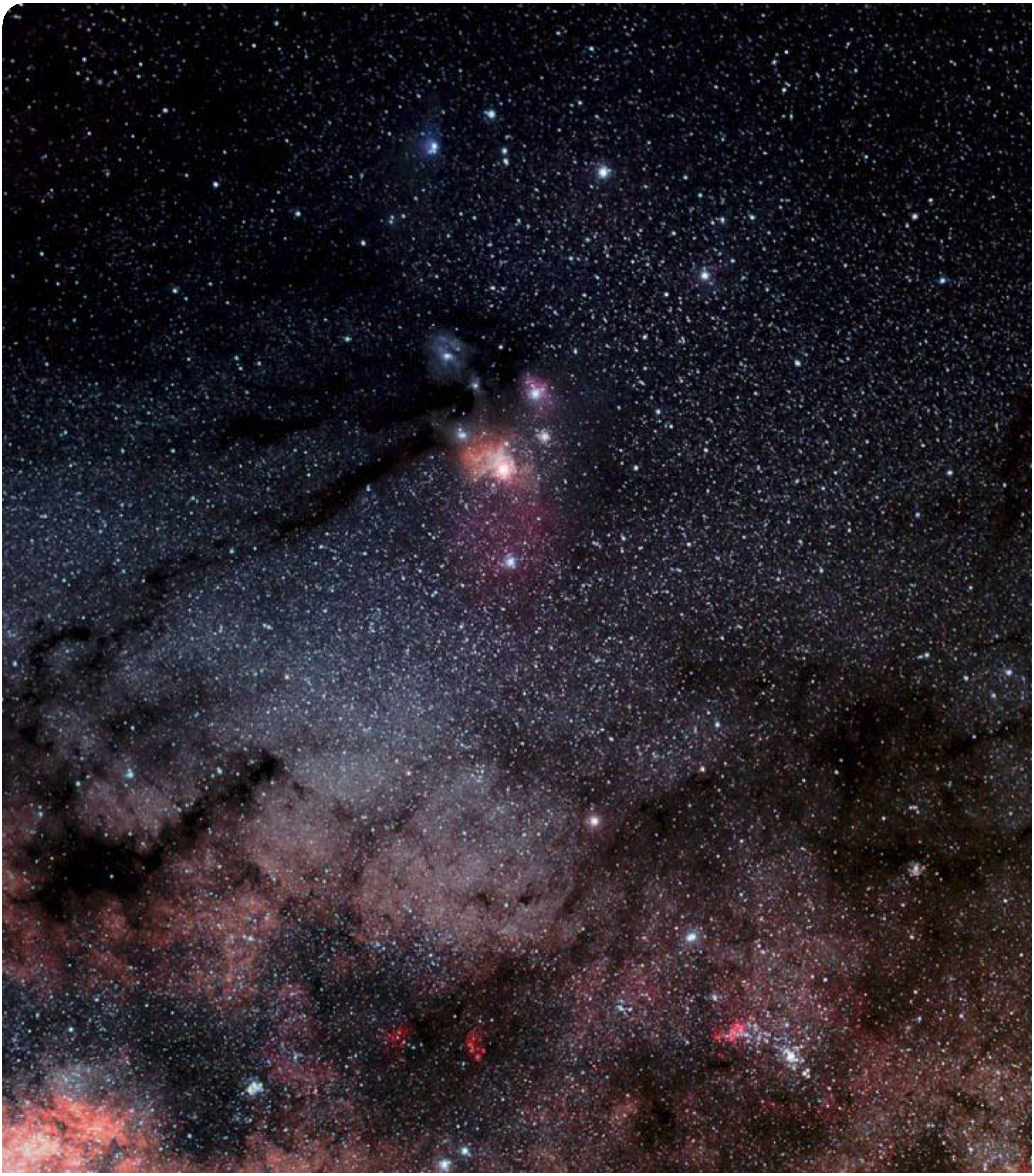
Comet C/2006 OF2 (Broughton) was passing through the constellation Auriga at the time of this image. The comet was about 179 million miles (288 million km) from Earth. (8-inch Celestron Schmidt-Cassegrain telescope at f/6.3, Canon 350D digital SLR, ISO 1600, twenty-two 3-minute exposures, taken January 12, 2009, between 8:33 P.M. and 9:45 P.M. CST) • Craig and Tammy Temple, Hendersonville, Tennessee



The Bear Claw Galaxy (NGC 2537) is a dwarf irregular galaxy in the northern constellation Lynx. It glows dimly at magnitude 11.7 and measures 1.7' by 1.5'. (14-inch Meade Schmidt-Cassegrain telescope at f/10, SBIG 2000XM CCD camera, LRGB image with exposures of 100, 20, 20, and 20 minutes, respectively) • Joe Petrick, Chesterland, Ohio

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.



The Scorpius region offers a terrific combination of stars, bright and dark nebulae, and star clusters. The bright star above center surrounded by nebulosity is Antares (Alpha [α] Scorpii). Globular cluster M4 sits to the upper right of Antares. The open star cluster to the lower right is the Northern Jewel Box (NGC 6231), part of a region called the False Comet. (Canon XSi digital SLR, Sigma 28mm lens at f/4, ISO 1600, forty-five 2-minute exposures, combined with Canon XSi digital SLR, Nikon 85mm lens at f/4, ISO 1600, fifty-three 2-minute exposures) • **John A. Davis, Dallas**

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